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WEEKLY 6 November 2021

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Can the UK become a new space pioneer?

In 2022, UK spaceports will be capable of hosting space launches for the first time. It is part of an ambitious plan to make the UK a meaningful actor in space. But is the country ready for the challenge? This *New Scientist* debate will explore how the UK's space efforts could unfold in the coming years. Join us for this free event on 18 November from 6pm GMT (1pm EST).

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Online

Covid-19 daily update

Stay on top of all the most crucial developments in the pandemic with our briefing, updated at 12pm GMT every weekday. We round up the latest coronavirus news and give links to exclusive features and interviews.

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Podcast

Weekly

This week's episode begins with a look at the *UN's Emissions Gap Report 2021*, which has found that even if countries stick to their emissions pledges, the planet will still warm by a catastrophic 2.7°C. Legendary sci-fi writer Kim Stanley Robinson drops in to talk about his climate heroes, geoengineering and the future of the planet. Plus: a signal from space looked like it was sent by aliens... but probably wasn't. And why sperm quality is declining in US men.

newscientist.com/nspod

SDA/BAS

Epic voyage The RRS Sir David Attenborough will head to Antarctica

BARRY NEAL/GETTY IMAGES

Vegan junk food? Plant-based diets aren't always a healthy choice

Video

Aboard an ice breaker

The UK's newest polar research vessel, the RRS Sir David Attenborough, has sailed into London ahead of its first trip to Antarctica. Our producers went aboard to check it out. The ship carries an impressive array of equipment, including an autonomous submarine named Boaty McBoatface. Don't forget to subscribe to our channel.

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Newsletter

Health Check

Get Clare Wilson's wonderful, weekly newsletter on health and fitness delivered free to your inbox. The latest issue looks at how people who choose a vegan diet today often end up eating lots of highly processed food that's not good for their health.

newscientist.com/health-check

Newsletter

> **"Even those who aren't fully vegetarian or vegan are eating more plant-based foods"**

Calendar 2022

Our calendar showcases a year of fantastic science photography, with the shortlisted entries from our 2021 photography awards. It has all UK bank holidays along with key dates in the scientific calendar – perfect for helping you stay organised.

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Zooming out on Alzheimer's

We have been focusing on a single cause for far too long

FOR nearly three decades, we have waited anxiously for a blockbuster drug that could defeat Alzheimer's disease. We believed we had identified the culprit behind this debilitating condition: sticky clumps of the protein beta-amyloid in the brain. Even as drug after drug homing in on this target failed to make a difference to symptoms, we continued to pour more money into the effort.

Regrettably, it is now becoming clear that this time could have been better spent zooming out from beta-amyloid, to look at the big picture of possible Alzheimer's causes.

Doing so reveals a far more complicated and insidious illness. It seems to be a condition that doesn't have a lone underlying trigger, but instead results from multiple overlapping processes and risk factors, which you can read about in detail in our cover story on page 46.

By thinking of Alzheimer's in the same way as we do multifaceted conditions like heart disease, researchers are now combining knowledge from across disciplines to identify, and tackle, the many known risk factors.

> "There is a real possibility that we could dismantle Alzheimer's by a thousand tiny cuts"

This new approach comes not a moment too soon, because 10 million new cases of dementia are diagnosed globally each year. The vast majority of these, between 60 and 70 per cent, are Alzheimer's disease. As people are living longer than ever, the number of people living with dementia is predicted to almost double every 20 years.

Accepting that Alzheimer's is more complicated than we thought might seem disheartening. And yet, targeting the many factors implicated in the disease, including the role of infections, diet, sleep habits and inflammation, puts at least some control back in our own hands, because these are things we can all do something about. It means we don't have to simply wait for pharmaceutical companies to deliver: we can also cut our own chances of getting dementia.

Tunnel vision has held us back for too long. With this new approach, a single blockbuster drug might well be out of the picture, but instead, there is a real possibility that we could dismantle Alzheimer's by a thousand tiny cuts. ▮

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MARIO TAMA/GETTY IMAGES

A deforested section of the Brazilian Amazon in 2017

COP26

An end to deforestation?

The first major pledge from the COP26 climate summit is a plan to save the world's trees by 2030, reports **Adam Vaughan**

NATIONS representing 85 per cent of the world's forests have pledged to end deforestation by 2030 in a renewed effort to stem the carbon emissions released by trees being cleared, nearly all for agriculture.

The Glasgow Leaders' Declaration on Forests and Land Use, issued on 2 November by more than 100 countries plus the European Union at the COP26 climate summit in the UK, comes alongside £14 billion of new funding to combat forest loss over five years. The money is being provided by 12 nations, including the UK, plus private organisations, including the Bezos Earth Fund.

Experts welcomed the renewed focus on forests and the new funding, but warned that the way deforestation is tackled will be key to whether the 2030 goal is met.

"We cannot reach climate goals if we don't keep trees standing," says Frances Seymour at the World Resources Institute, a think tank in Washington DC. She says it is good that trees are one of the UK government's four priorities at COP26, along with climate finance, ending coal use and phasing out cars that use fossil fuels.

The 2030 goal is identical to one made seven years ago by a smaller group of countries, known as the New York Declaration on Forests. They also set an interim goal of halving deforestation by 2020, a target missed by a wide margin.

But a key difference is the new plan is signed by several countries that were missing last time, including those with the greatest deforestation rates, such as Brazil. "Having all the main players on it is significant, that is a big step," says Stephanie Roe at the University of Virginia.

While £14 billion looks big, it still isn't on a par with what will be needed to meet the deforestation targets of the 2015 Paris climate deal. Meeting those would mean spending an estimated $45 billion to $460 billion a year to protect, restore and enhance forests. Nonetheless, Roe says the funding is a "very welcome and critically needed addition".

So, is it realistic that deforestation could be halted by 2030? "Yes, I think it is feasible. It is difficult, but it is feasible," says Seymour. "The main constraint in most places is political will."

She says there is precedent for action, citing the example of Brazil in the early 2000s, which successfully used policies to slow deforestation rates at the time. Other reasons for hope include a growing awareness among governments that trees aren't just important for locking away carbon, but also for protecting against the impacts of extreme weather, such as preventing soil erosion. Modern satellite monitoring of forest loss helps too, Seymour adds.

However, there is little detail in the new declaration on how the goal will be met – such as paying countries for preventing projected clearances – or how progress will be monitored. The goal also isn't binding. Seymour says that the new funding won't help unless simultaneous efforts are made to cut off the agricultural subsidies that drive much logging.

We need to know that measures will be used to stop forest loss, says Constance McDermott at the University of Oxford. "It is not possible to comment on these very bold and flashy promises without seeing, in full view and detail, how they will be operationalised," she says. It is key that efforts benefit local and Indigenous communities as well as biodiversity, rather than consolidating money and power in the hands of a few states and corporations, she says. ■

The latest news from COP26
Online every weekday
newscientist.com/COP26news

Analysis COP26

India's pledge on net zero

The nation's 2070 net-zero goal is later than others, but still means that all major emitters now have an end in sight for fossil fuels, says **Adam Vaughan**

INDIA has said it will reach net-zero carbon emissions by 2070. This is decades later than many other countries, but it marks the first time the country has put an end date on its contribution to climate change.

The target was announced by prime minister Narendra Modi at the COP26 summit in Glasgow, UK, on 1 November, amid warnings by world leaders about the dangers of failing to act fast enough on emissions.

"A year ago, no one would have expected India to announce a net-zero target at COP26," says Thomas Hale at the University of Oxford. "But that's the nature of tipping points. Once critical mass is reached, it is very hard not to join in." He says that countries representing 90 per cent of global GDP are now covered by a net-zero target.

However, India's 2070 date is 20 years later than the 2050 pledged by the UK, US and other high-income countries, and later than the 2060 chosen by China, Russia and Saudi Arabia.

"The date is late, but more important is that India committed to zero at all, which was thought to be unlikely by many," says Niklas Höhne at the NewClimate Institute, a German non-profit organisation. The long-term commitment will also shape investments today, he adds.

With a population of 1.38 billion and growing, India is the world's fourth biggest emitter after China, the US and the European Union. But it has some of the lowest per capita carbon dioxide emissions, at 1.9 tonnes per person in 2019, compared with 5.5 tonnes in the UK and 16 tonnes in the US, a point Modi has repeatedly emphasised in the past.

The new goal wouldn't see the world stick to the Paris Agreement's aim of keeping temperature rises to 1.5°C above pre-industrial levels, as that requires global emissions to reach net zero around 2050. Hale says that it is largely the fault of richer countries, which used much of the world's "carbon budget", leaving little room for countries like India to grow their economies.

Modi also declared four other steps, including 50 per cent of India's energy being sourced from renewable sources by 2030. Although he used the word "energy", the target is very likely to cover only electricity, as such a goal for energy would be nigh-impossible for India.

The country's renewable energy capacity should reach 500 gigawatts by 2030, up from around 134GW today, and it is also aiming to cut its projected CO_2 emissions by a billion tonnes between now and 2030 and cut its carbon intensity – emissions released for each unit of GDP – by 45 per cent.

Modi said that while the world had focused on cutting emissions, it hadn't paid enough attention to adapting to a warming world. "This is an injustice to those countries more impacted by climate change," he said.

India's 2070 pledge means that all major emitters have now declared a net-zero deadline, effectively putting a backstop on when the world will stop burning fossil fuels. Last week, China, the world's biggest polluter, formalised its 2060 goal in a plan submitted to the United Nations. The blueprint also committed to peaking emissions before 2030.

The COP26 summit was opened by UK prime minister Boris Johnson likening the situation for world leaders faced with climate change to being James Bond strapped to a ticking doomsday device. He said the meeting in Glasgow could become the moment humans began to "defuse that bomb".

Broadcaster and naturalist David Attenborough gave an emotional speech, urging leaders to stabilise atmospheric CO_2 concentrations and to turn "tragedy into triumph". He added: "Our motivation should not be fear, but hope." UN secretary general António Guterres issued a bald warning that: "We are digging our own graves." Meanwhile, US president Joe Biden apologised for the US pulling out of the Paris Agreement under Donald Trump.

One of the most striking speeches of the day came from Mia Amor Mottley, prime minister of Barbados. "1.5°C is what we need to survive. 2°C is a death sentence for the people of Antigua and Barbuda," she said, referring to one of the island nation's Caribbean neighbours. "Can we find it within ourselves to bring Glasgow back on track or do we leave today believing it was a failure before it starts?" ▮

1.38bn

India has the world's second largest population after China...

1.9

... but its per capita CO_2 emissions, in tonnes per person, are some of the lowest in the world

500

Renewable energy capacity, in gigawatts, that India wants to achieve by 2030

United Nations
Climate Change
UN CLIMATE CHANGE CONFERENCE UK 2021

Indian prime minister Narendra Modi speaking at the COP26 summit

ALASTAIR GRANT/AP/SHUTTERSTOCK

Neuroscience

Brain implants help with flexible thinking

Helen Thomson

ELECTRICAL brain stimulation in people with pre-existing brain implants has allowed them to think more flexibly and clear anxious thoughts, suggesting it has the potential to treat conditions like depression.

Alik Widge at the University of Minnesota and his colleagues found that applying an electric current within the centre of the brain boosted people's ability to rapidly adapt to changing goals, known as cognitive control, and in some cases improved their feelings of well-being too.

The inability to disengage from habitual ways of thinking is commonly seen in people with mood disorders, such as depression and obsessive compulsive disorder. In these conditions, people are often unable to extricate themselves from thought processes triggered by habits or distress.

> "It may be possible to stimulate the brain only when necessary to relieve specific brain activity"

Widge recruited 21 people who already had electrodes placed in their brain as a treatment for epilepsy. They didn't have depression, but some had mood disorders associated with epilepsy. He and his team used these electrodes to provide small bursts of stimulation to the brain while participants performed a cognitive control task, in which they were shown a trio of numbers between one and three on a screen. Two of the numbers were always the same, and the participants had to identify the odd number out and press the corresponding key on a keypad.

In some tasks, the position of the unique number matched its physical position on the keypad, in other tasks it didn't. The task forces people to use cognitive control to overcome the difference between where the number is on the screen and the keypad.

When their brains were stimulated, participants were around 5 per cent faster at answering correctly. It might not seem like much, says Widge, but you don't need a lot of change in flexible thinking to help people make small tweaks in their life that can then accumulate over time and help change behaviours.

Although the participants couldn't tell when the stimulation was switched on and off, in trials where it was on, some people reported that their thoughts were more focused and background anxiety was easier to ignore, suggesting the stimulation was having an influence (*Nature Biomedical Engineering*, doi.org/g4gm).

In further experiments, the team only stimulated the brain when participants' accuracy fell below a specific threshold. This "closed loop" technique made participants 10 per cent faster, says Widge. The researchers later showed that they could identify falls in accuracy based on patterns of brain activity alone.

As a result, it may be possible to record and stimulate the brain only when necessary to provide relief from specific brain activity.

Because the implants are invasive, this would probably be only used for treatment-resistant conditions. Doctors have already started treating psychiatric conditions in this way, with varied results, says Keyoumars Ashkan at King's College Hospital in London. Personalised, closed loop delivery, may be key to effective treatment, he says. "Much research still needs to be done, but at least we now have a starting point." ▮

Animal behaviour

Barn owls may create mental maps just like us

Jason Arunn Murugesu

ANAN KAEWKHAMMUL/SHUTTERSTOCK

Neurons known as place cells may help barn owls keep track of their location during flight

OWLS may make maps of their surroundings in their brains just like humans do. If this ability is indeed present in non-mammals as well as mammals, it means it may have evolved hundreds of millions of years ago.

To check for this in barn owls (*Tyto alba*), Yoram Gutfreund at Technion-Israel Institute of Technology and his colleagues implanted a wireless neural recording device into the brains of six of the birds. The team used these to analyse brain activity as the birds flew back and forth between two perches.

The group was looking for signs of place cells – neurons that fire when an animal is in a specific place. These cells let an animal make a mental map of its surroundings and have been found in people, rodents and bats, but not in flying birds, although they have been seen firing in a tufted titmouse, a type of songbird, as it walks.

For the owls, the team tracked each bird for about 20 minutes, following their flights with eight high-speed infrared cameras.

By combining data from the neural recordings with the infrared footage, the team found that certain hippocampus neurons fired more strongly at specific points in the flight path and depending on which direction a bird was flying (bioRxiv, doi.org/g4gf).

However, the team notes that the cells involved might not be place cells at all. They could just be time-sensitive, with their firing dependent on how long the birds have been in the air.

Kate Jeffery at University College London says that she finds the evidence suggesting these neurons are in fact place cells "fairly convincing". The cells' properties are like those seen in rodents doing a similar task involving animals moving in a straight line, she says.

"The findings are consistent with emerging findings that many of the phenomena we have been studying in mammals have counterparts in non-mammals, suggesting an ancient evolutionary origin – more than 300 million years [ago]," says Jeffery. ▮

Technology

Facebook is now Meta – but why, and what even is the metaverse?

Chris Stokel-Walker

PREPARE for plenty of confusion in the coming months, because Facebook – whose products are used by more than 3 billion people worldwide – has decided to rebrand itself. Here is everything you need to know.

What has happened?

Facebook, the company that owns platforms including Facebook, Instagram and WhatsApp, rebranded as Meta on 28 October. "Right now, our brand is so tightly linked to one product that it can't possibly represent everything that we're doing today, let alone in the future," said CEO Mark Zuckerberg, announcing the change. "Over time, I hope that we are seen as a metaverse company, and I want to anchor our work and identity on what we're building toward."

Sorry, what is a metaverse?

The name for a shared online 3D virtual space that a number of companies are interested in creating as a sort of future version of the internet.

"In this future, you will be able to teleport instantly as a hologram to be at the office without a commute, at a concert with friends, or in your parents' living room to catch up," Zuckerberg wrote in a letter announcing Facebook's rebranding as Meta.

But that is in the future. The metaverse unveiled by the company in August looks like *The Sims* or another immersive world: the 2003 video game *Second Life*.

MICHAEL NAGLE/BLOOMBERG VIA GETTY IMAGES

CEO Mark Zuckerberg announcing Facebook's rebranding as Meta

Why is Zuckerberg doing this?

"My suspicion is that this is about owning the operating system of the future, and Facebook's experience of being an app on other people's – rivals' – operating systems," says Anupam Chander at Georgetown University Law Center in Washington DC. "They don't want to be prisoner on other people's platform."

Doesn't Meta have bigger things to worry about?

There has been a steady drip of negative stories following the release of the Facebook Papers, internal documents highlighting issues with the company, secreted out of the firm by whistleblower Frances Haugen. Some see the new name as a way to distract from this narrative.

"All the bad press and political battles it is currently fighting have to do with its social networking products, so launching something entirely new – in their minds – is a way to completely rebrand and start fresh, without changing much with the existing problematic products," says Taina Bucher at the University of Oslo, Norway.

What happens if Meta succeeds?

Meta could play a pivotal role in our lives as the sole company underpinning the metaverse if its vision of the future becomes a reality. The company has struggled with outages that removed the ability to communicate for large parts of the world in recent months, and if such a thing were to happen in an all-pervasive VR universe like the metaverse, the consequences could be huge. ▮

Solar system

Mars rover tests a new way to hunt for alien life

NASA's Curiosity rover has tested a new way of seeking signs of life on Mars. Although it found no such evidence, the trial suggests future missions to other worlds could use the same method.

In March 2017, the rover scooped material from the Bagnold dunes, a band of sand dunes stretching tens of kilometres on the Martian surface. In December 2017, Curiosity transferred some of this material into its Sample Analysis at Mars (SAM) instrument.

SAM has 74 "cups", or holders, that are used to analyse samples. Most are otherwise empty, with the samples in them heated by the rover so they can be studied, but nine contain solvents that can dissolve materials, which allows us to better work out their compositions. The test in December 2017 saw some of these solvents used for the first time, to see whether this technique could be useful on other worlds.

The results showed it could. After years of careful work on Earth to understand what they were seeing, Maëva Millan at Georgetown University in Washington DC and her colleagues found evidence for organic molecules in the samples that would have been missed by the rover's heat-based analysis. While these molecules aren't concrete evidence of life, such as amino acids, the results show the benefits of these so-called wet chemistry derivatisation experiments (*Nature Astronomy*, DOI: 10.1038/s41550-021-01507).

"We have proved that this experiment can work," says Millan. "That means we can do this same experiment again on different minerals like clay and sulphates that can better preserve organic molecules."

That includes further studies on Mars by Curiosity in regions that are more promising in the hunt for life. Its sister rover, Perseverance, is also seeking signs of life, but lacks the same "wet chemistry" equipment.

The technique will be used on upcoming missions, such as Europe's Rosalind Franklin Mars rover launching in 2022 and NASA's Dragonfly, a drone that will explore the surface of Saturn's moon Titan in 2036. ▮

Jonathan O'Callaghan

Technology

Smart scheduling for computer tasks cuts emissions by a third

Matthew Sparkes

SHIFTING large computing jobs to nights or weekends could reduce their associated carbon emissions by a third.

The International Energy Agency (IEA) found that data centres, which are used by businesses including banking and social media firms, consumed around 250 terrawatt hours of power in 2019, or about 1 per cent of global electricity use. The IEA predicts this will rise to around 270 terrawatt hours in 2022.

Philipp Wiesner at the Technical University of Berlin says that in order to lower associated carbon emissions, this energy use needs to be reduced, and could also be scheduled at times when renewable sources make up the largest amount of the energy mix on power grids. He and his colleagues simulated the effect of changing the timing of large computing jobs to hours when the energy mix is skewed towards renewable power.

In one set of tests, the researchers simulated a company running a nightly task every day for the year 2020. In the baseline experiment, the task was scheduled to run each night at 1 am, but in other tests the task could be completed at any point during a 16-hour window. The model was given real-world historical energy mix information from each region during that year and told to minimise carbon emissions.

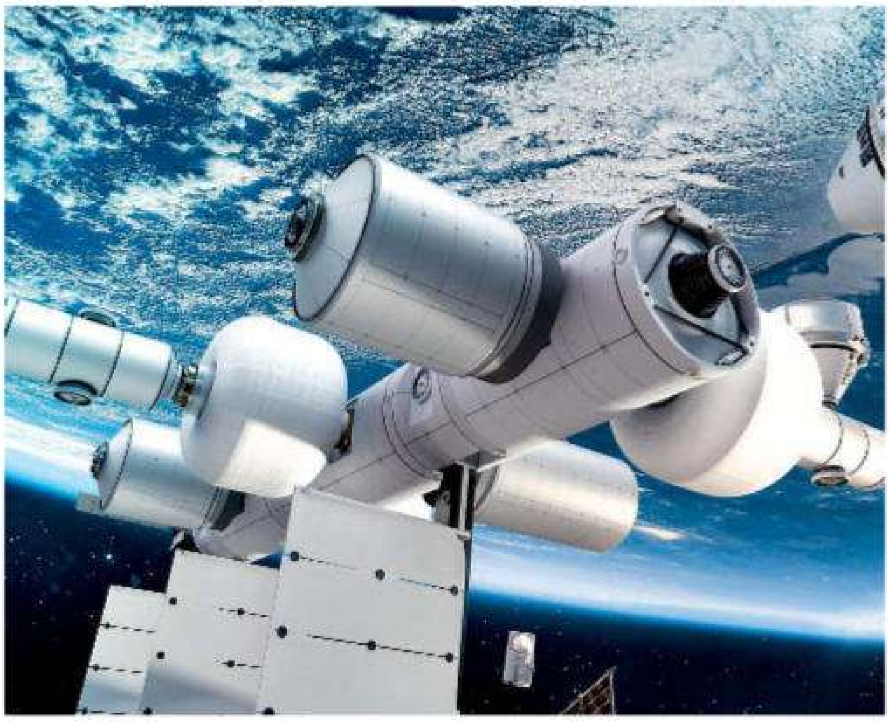
The simulation showed that in Great Britain, running the task when emission potential was lowest during the window would save 7.4 per cent of its carbon emissions over the year. In California, the savings exceeded 33 per cent (arxiv.org/abs/2110.13234).

Ralitsa Hiteva at the University of Sussex, UK, says that "such solutions are exactly the type of thing that we need more of... to move closer to net zero".

Analysis Space exploration

Can Blue Origin replace the International Space Station?

The space-flight firm owned by Amazon founder Jeff Bezos is hoping to build a new orbital outpost, says **Leah Crane**



BLUE ORIGIN

An artist's impression of the Orbital Reef space station

THE Orbital Reef space station, which Blue Origin is developing in partnership with other space firms including Sierra Space and Boeing, is intended to be a multipurpose destination in orbit. Different companies and governments could pay to send their own astronauts and experiments there, and space tourists could visit, says the firm. The station is proposed to be slightly smaller than the International Space Station (ISS), with capacity for 10 astronauts. The ISS generally carries seven crew members, but it has had as many as 13 at a time.

"We will expand access, lower the cost, and provide all the services and amenities needed to normalize space flight," said Blue Origin's Brent Sherwood in a statement. "A vibrant business ecosystem will grow in low Earth orbit, generating new discoveries, new products, new entertainments, and global awareness."

So would the private station be a viable replacement for the ISS? The ageing station, which is a partnership between the US, Russia and other nations, is only funded until 2024, with an extension to 2028 looking probable, but it can't last forever.

Blue Origin says its space station will be fully operational in the late 2020s, but deadline slippage is common when it comes to huge space-related projects like this one. "They can dream of being fully operational in the late 2020s, but in the space sector they often aim for aspirational targets and if they miss it by a year or two or three then they at least have something they're aiming for until then," says space analyst Laura Forczyk. "It's almost inevitable that things take longer and are more expensive than planned."

10

Number of astronauts that could be housed on Orbital Reef

Blue Origin and its set of commercial partners aren't the only companies with space station ambitions – Nanoracks and Lockheed Martin announced their plans on 21 September for a smaller station called Starlab that could host up to four astronauts, and Axiom also has a station under development. Still, it is unclear if any of these will be ready in time, meaning the late 2020s could see a period in which China's space station will be the only human habitat in orbit, although the country has promised to let other nations use its facility.

"I am alarmed by what I see as the potential for a gap [in the US orbital presence]," said Axiom executive Mary Lynne Dittmar in a US Congressional hearing on 21 October. Because of US legislation preventing cooperation between NASA and China, if there is a gap, it will ground NASA astronauts and make it difficult to test crucial technologies for the agency's other space missions, including the Artemis programme to send humans back to the moon.

NASA hasn't awarded any funding to Blue Origin or Nanoracks – Axiom has a contract to attach a module to the ISS as part of its station's development – so the businesses themselves are putting up the money for now. That is a double-edged sword, because a lack of government investment could introduce delays, but also shows that the commercial sector is keen to push ahead.

"These two new concepts are not only serious concepts with serious partnerships, they're also contributing their own internal funds," says Forczyk, "That signals that they're serious about this, that they're not just waiting for NASA to provide funds – when a company gets serious about something, that's when they put in their own money."

Field notes ToddlerLab, London

The technology letting us peek inside the brains of children

Clare Wilson

THREE-year-old Sophie is sitting at a low table, trying to build a house out of large plastic bricks, as a nearby adult gives gentle encouragement. It could be a scene from any nursery school, but for the incongruous apparatus that Sophie wears: a snugly fitting black cap studded with sensors and sprouting multiple thick, black wires. It looks slightly sinister, but the harmless cap is letting researchers do something that has never been done before: peer inside the brains of active toddlers.

Sophie is a participant at the ToddlerLab, a state-of-the-art facility at Birkbeck University of London that is investigating child development. The wires from the cap she is wearing run from the top of her head into two small recording units tucked into her backpack. This apparatus enables the team to image her brain as she moves around, while a pair of motion-capture gloves and 16 discrete cameras evenly spaced around the ceiling record the movement of each of her fingers down to one-hundredth of a second.

Brain imaging has taught us a lot in the past two decades about the structure and function of the brain in sickness and in health, but most approaches have limitations. The standard magnetic resonance imaging (MRI) device is a huge noisy machine that people have to lie inside, quiet and still, for up to an hour at a time.

This means MRI can't be used easily on young children or to study any activities that require moving around – which are significant chunks of human existence.

Now the technology being used at the ToddlerLab, called functional near-infrared spectroscopy or fNIRS, is changing that. With equipment small enough to sit inside a lightweight cap, it beams infrared light through the skull, so that it is scattered into nearby receivers, also sited in the cap.

Brain scanning and motion-capture gloves reveal how Sophie sets about making a house out of building blocks

The amount of light that is absorbed depends on how much oxygenated blood it passes through, which gives an indication of how often neurons are firing in those regions of the brain. In other words, it reveals how hard your brain cells are working, says Lisanne Schröer at Birkbeck. "It's giving us the first looks at children's brains when they are acting naturally."

That isn't to say that the work always goes smoothly. "Toddlers are not the easiest group to work with," says Schröer. Sometimes her subjects decide they don't want to wear the special "scientist's hat", for instance. "If they say 'no', that means no."

Some of the children who visit today are shy and cling to a parent's legs – so getting down on the floor and blowing bubbles into the air is all part of a day's work for the neuroscientist team.

"This technology is giving us the first looks at children's brains when they are acting naturally"

Another child, Finn, seems to hold no fears, but is keener to build a tall tower than the house requested. "Every session is different," says Schröer.

DAVE STOCK

The project is investigating how we learn to plan and achieve goals by breaking them down into smaller sub-goals, by comparing children who are 3 and 5 years old. Once the children are happy wearing the cap, they are asked to build a simple house shown in a video, which means they need to first build each wall, then put the roof on top.

Using the motion-capture gloves, the team has previously found that when carrying out sub-goals – such as reaching for a brick – the child's non-dominant hand freezes for a few seconds. "This suggests they are focusing on executing the sub-goal," says Schröer.

But planning seems to take place at a different point. The current study indicates that it is when children are between sub-goals that brain activity rises in their prefrontal cortex, the part of the brain that is involved in planning, perhaps because they are selecting their next task. At least, this is the case for those children who complete the house.

Longer-term, a better understanding of brain development could help children who may develop atypically, such as those with autism or attention deficit hyperactivity disorder (ADHD), says team member Paola Pinti.

The technology has other uses beyond studying children. The use of wireless recorders with the infrared brain imaging is enabling researchers to examine adults walking around in the real world, talking to others, or in the workplace. "It opens up enormous opportunities," says Schröer. "It's a whole new field." ■

Technology

EU's search-and-rescue drones

Uncrewed aircraft could drop life rafts to migrants in the Mediterranean Sea, reports **David Hambling**

TEKEVER

A Tekever drone of the kind that will drop rescue rafts

RAFT-DROPPING drones will soon be helping with rescues at sea. The European Maritime Safety Agency (EMSA) has awarded a €30 million contract for uncrewed aircraft to patrol European waters.

The remotely piloted aircraft will be able to airdrop a rescue raft that can carry up to eight people. It could be used to rescue migrants attempting to cross the Mediterranean Sea, but critics say the drones may end up being used to deter migration attempts.

EMSA announced the four-year contract on 14 October with the REACT consortium, which comprises a subsidiary of the French space agency called CLS and drone-making firm Tekever, based in Lisbon, Portugal.

The project will involve four of Tekever's twin-prop AR5 aircraft. These have a wingspan of 7 metres and can cruise at 100 kilometres per hour for up to 12 hours.

In addition to the life raft, the drones carry visual and infrared cameras, maritime radar and a detector to pick up and locate emissions from mobile phones.

To drop a raft close enough to people in the water for them to reach it easily, but without risking hitting them, Tekever's drone has AI that uses camera data with detection algorithms to determine the position of people in the water.

It combines this with data about the aircraft height and speed, plus weather data, to calculate an exact drop point. This allows it to place the raft where it is needed, after a go-ahead from the remote operator. CLS will provide satellite communications so the AR5 can be controlled from a distance.

It is estimated that more than 1400 people drowned in the Mediterranean Sea in 2020 while attempting to migrate. "Drones carrying small life rafts clearly have the potential to save lives in certain situations," says Chris Cole at Drone Wars, a UK non-governmental organisation that tracks government use of drones.

"I am very sceptical that this UAV [uncrewed aerial vehicle] will not end up being used by border force agencies at some point, but it's hard to say conclusively at this stage," says Cole. "We know the AR5 has been used by EMSA for 'general maritime surveillance'." EMSA already uses drones to patrol several seas, and collaborates with Frontex, the European Union's border and coastguard agency.

A spokesperson from Tekever says: "Tekever AR5 will not be used to look for migrants, or gather data on migrant boats which would be passed to Frontex."

Cole also thinks the drones could deter migrants. Newspaper reports suggest that migrants sometimes attempt to escape detection by crossing on foggy days, but the AR5 sensors still work in these conditions. If the area is fully patrolled by drones, some people may choose not to set off at all, knowing that they could be spotted and potentially stopped. He says the drones aren't a substitute for an effective search-and-rescue service.

In addition to monitoring migration, the EMSA programme could also use the drones to help counter illegal fishing, pollution and smuggling. ▮

Evolution

Habitats may dictate whether vipers have nose or eye horns

THE small horns that stud the heads of many viper species may play a role in camouflage, suggesting they evolved as a result of the varying environments the snakes inhabit.

Theo Busschau and Stéphane Boissinot at New York University Abu Dhabi in the United Arab Emirates studied whether horn evolution in these reptiles could be tied to environmental factors by analysing the physical features of 263 viper species to determine their evolutionary relationships to each other. They also compared horn placement – over the eyes or on the nose – with the vipers' habitat preferences.

Eyebrow horns were associated with vipers that live in trees or open habitats, and nose horns were linked to those living on the forest floor. "The common factor between arboreal habitats and rocky or sparsely vegetated habitats is a lack of cover," says Busschau. Eyebrow horns "could disrupt the outline of a viper's head and possibly also conceal the eyes, allowing them to blend in better with their environment", he says. On forest floors, nose horns could make viper heads harder to spot among leaves and twigs (bioRxiv, doi.org/g4gs).

The horns have independently evolved dozens of times in vipers across the world, suggesting that environmental pressures are pushing vipers to converge on the feature, the researchers argue.

"Eyebrow horns could disrupt the outline of a viper's head, concealing its eyes in open habitats"

Ken Toyama at the University of Toronto in Canada wasn't too surprised by the findings. Forest habitats, particularly in the tropics, "provide some of the most structurally diverse environments on Earth", he says. "Complex habitats provide a good opportunity for [visual camouflage] to evolve."

Busschau says he plans to study the vipers' genomes to find the DNA changes that underpin how the horns keep evolving. ▮

Jake Buehler

Immunology

Two people suppressed HIV for years while pausing their medication

Clare Wilson

TWO people with HIV who were able to stop taking medication for several years without becoming ill from the virus offer clues for future strategies to suppress the infection. But both eventually had to restart taking medication, showing the current limitations of such approaches, says Tae-Wook Chun at the National Institutes of Health (NIH) in Maryland.

People with HIV can avoid becoming ill by taking lifelong medicines that stop the virus from multiplying, but copies of the virus remain in their immune memory cells throughout the body. This means that for most, if they stop medication, the virus starts multiplying again and levels in the blood rebound, requiring a return to drug therapy.

A few individuals who pause their HIV medication don't see their blood virus levels quickly rebound, but it is unclear why. They are sometimes called "post-treatment controllers". The phenomenon seems to happen more often in people who begin HIV drug treatment in the first few weeks after infection, perhaps because the virus isn't able to become established in so many of their immune cells.

The latest study looks at two people who both began early HIV treatment and later stopped their medication as part of an NIH trial of a therapeutic vaccine to treat HIV infections, although they received a placebo version of the vaccine. When the virus didn't start multiplying at the end of the six-month trial, the men chose to stay off their medication and continue having frequent blood tests, even though they had been told they had the placebo.

The pair were able to continue without HIV medication for 3.5 and four years, but different immune mechanisms seemed to be responsible in each case (*Nature Medicine*, doi.org/g36v).

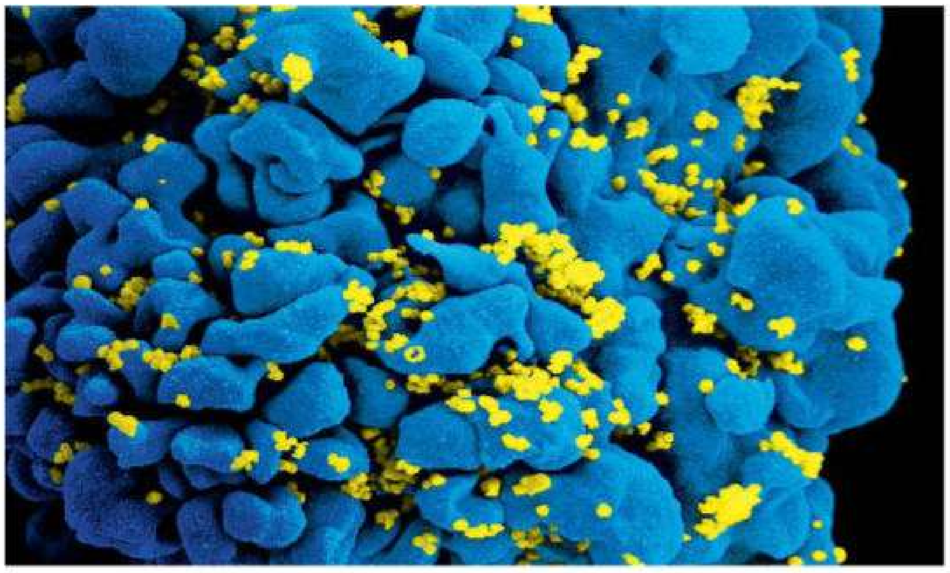
There are two main arms of the immune system: antibodies and T-cells. It was thought that T-cells, which directly kill virus-infected human cells, were more important for post-treatment controllers. But Chun and his colleagues found that while T-cells were responsible in one man, antibodies were suppressing virus multiplication in the other. "He had an amazing antibody response that probably completely contained viral replication," says Chun.

This second man had to restart medication because he became infected with another HIV infection, which was resistant to his antibodies. HIV viruses are highly variable and there are many genetic subtypes circulating.

The first man, who was being protected by T-cells, saw three relatively small rises in the level of virus in his blood followed by spontaneous falls. After 3.5 years, he chose to restart medication without telling his doctors, which they discovered through a regular blood test.

The study shows that researchers looking at post-treatment controllers need to frequently test people's blood, both for new HIV infections and for evidence of HIV drugs even if they aren't being officially provided, says Chun.

HIV particles (yellow) emerging from an infected T-cell (blue)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Military technology

Powerful laser weapon to be tested by the US next year

THE US Army will demonstrate a 300-kilowatt laser weapon, its most powerful ever, next year. General Atomics Electromagnetic Systems (GA-EMS) and Boeing are building the device, which is the size of a shipping container and mounted on a heavy truck.

"The high power, compact laser weapon... will produce a lethal output greater than anything fielded to date," Scott Forney, president of GA-EMS, said in a statement.

The US Navy deployed the first high-energy laser weapon, known as LaWS, on the USS Ponce in 2014, with a reported 30 kilowatt output. Most military lasers tend to be in the 30 to 100 kilowatt range, which is mainly useful for shooting down small drones, so the power of the new weapon is a significant increase.

Typically, such weapons are based on multiple industrial fibre lasers, with the output combined into a single beam. The new weapon instead uses large slabs of glass connected in series. Such slabs have previously been hard to use due to waste heat and issues with beam quality, but GA-EMS says using them in series solves these issues and removes the need to combine beams from multiple fibre lasers.

The new laser is part of a US Army project to develop defensive lasers to shoot down incoming threats. Last year, it demonstrated a 10-kilowatt laser destroying small mortar rounds.

"The high power laser weapon will produce a lethal output greater than anything fielded to date"

Justin Bronk at UK security think tank Royal United Services Institute says the more powerful laser can take on bigger targets as well as engaging multiple targets in quick succession. "It will allow the system to engage a greater density of incoming threats, and also potentially engage threats which offer a shorter engagement window either due to speed or very low altitude flight trajectory," he says.

This might allow the laser to defend against ballistic and cruise missiles as well as drones, aircraft and helicopters, says Bronk.

David Hambling

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Evolution

Environment

Peat smoke used by whisky distilleries is climate concern

Jason Arunn Murugesu

Peat being cut and left to dry in the Scottish Highlands

DRIMAFILM/SHUTTERSTOCK

THE UK is the world's largest exporter of whisky, which has been distilled in Scotland for 500 years. But the peat used to flavour some Scotch whiskies is increasingly under the spotlight as the fight against climate change steps up.

The conservation of peatland will be a key talking point at the COP26 climate summit now under way in Glasgow, UK, because peat stores large amounts of carbon. Some estimates suggest that UK peatlands contain more than 3 billion tonnes of it – about the same as all the forests in France, Germany and the UK combined.

When peat is dug up, often to use as fuel or to make compost, carbon is released – and because peat takes thousands of years to form, it cannot be considered a renewable resource. This raises difficult questions for whisky producers.

For generations, peat smoke has been used to enhance the flavour of the barley that goes to make whisky. It is still used in about a third of malt whiskies produced in Scotland, and accounts for about 6 per cent of the peat dug up in the country, according to an analysis of the latest UK government figures, from 2014.

While it is plentiful in Scotland, the peat used in whisky is largely extracted from two areas: the Isle of Islay off the west coast, and Aberdeenshire in the north-east of the country.

NatureScot, a government agency responsible for Scotland's natural heritage, has had a deal with one whisky producer, Diageo, since 1974 to extract peat on Islay. However, the nature of that deal may change in the years ahead.

6%

of the peat extracted in Scotland is used to flavour whisky

"Extraction rights were granted to Diageo to support the whisky industry and prevent damage to other peatlands," says a NatureScot spokesperson. "However, as part of a review of our landholdings with the aim of delivering on net-zero targets we are urgently exploring with Diageo the opportunities to reduce emissions from the site."

"We recognise the important role peatbog ecosystems play in terms of biodiversity and climate change and we are committed to working with partners to ensure we manage resources as sustainably as possible for the future," says a spokesperson for Diageo.

Last year, the Scottish government promised £250 million to help restore the nation's peatlands and stop them leaking carbon, which will add to the pressure on whisky manufacturers to change their practices.

"I want distilleries to use the peat from sites that are already degraded, like when a new road is cut through," says Clifton Bain at the International Union for Conservation of Nature UK Peatland Programme. "There's been a myth around the industry that you have to take peat from certain places only, because they've got a unique flavour."

Removing peat from degraded sites, however, will mean abandoning tradition, and it is unclear whether whisky distilleries and drinkers would welcome such a move.

But Neil Godsman, a peat farmer in Aberdeenshire who supplies the whisky industry, is pragmatic. He isn't too disheartened about the fact that the peatbog he and his family have farmed for decades is nearing the end of its commercial life. "Peat is peat," he says. "It's the same everywhere." ▮

Animal behaviour

Red feathers signal social status in small songbird species

Christa Lesté-Lasserre

COMMON waxbills with the highest social ranks aren't necessarily larger in size or more intelligent than their peers – but they do have chest feathers that are a richer shade of red. This may be because individuals are so healthy that they can spare resources on accentuating their colours.

Patrícia Beltrão at the University of Porto in Portugal and her colleagues discovered this by evaluating dozens of common waxbills (*Estrilda astrild*) that were captured as adults in a large outdoor netted area.

The researchers measured the birds' body size and then used digital photography and reflectance spectrophotometry to determine the size and saturation levels of the red-feathered chest patches.

The common waxbill's red breast signals dominance

SAVERIO GATTO/BIOSPHOTO/ALAMY

They also ran standard behaviour tests on each bird to judge their intelligence, stress tolerance and level of aggression or passivity. Then, they monitored bird feeders in the netted area, recording when a bird recognised another as higher-ranking by giving up its place at the feeder.

The researchers found that the only obvious factor linked with rank and dominance was the saturation level of the red chest plumage, says Beltrão (*Animal Behaviour*, doi.org/g36n).

If a bird has more saturated red colouring, it could indicate that it is healthy enough to spare nutrients in food for pigment use, so the feathers could act as a "badge of honour", says Beltrão. "But that's just a hypothesis." ▮

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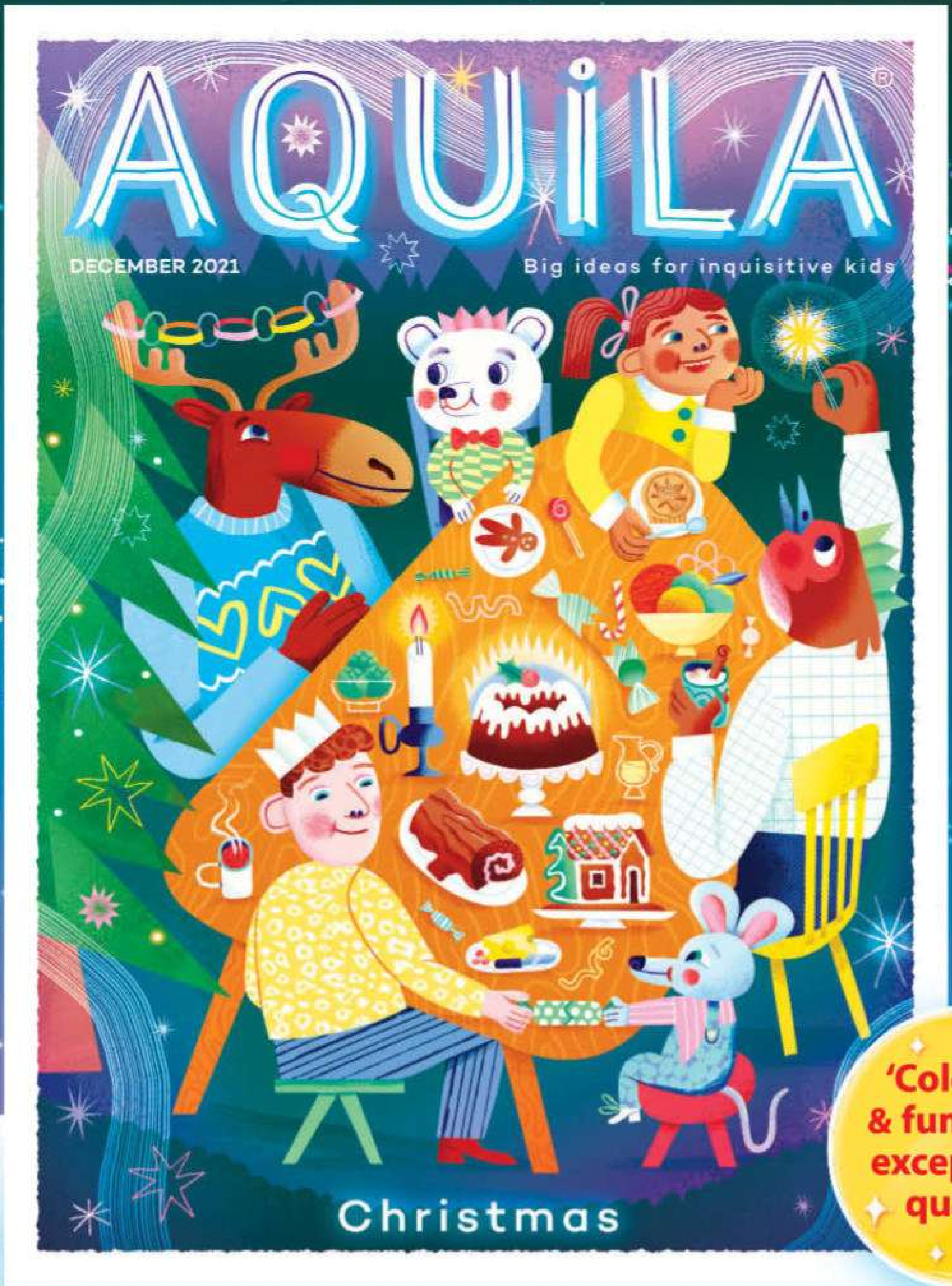

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Genetic engineering

Genetically engineered bacteria could one day heal us from inside our cells

Michael Le Page

BACTERIA have been genetically engineered to enter and live inside mouse immune cells, where they released proteins that altered the behaviour of those cells. The work is a small step towards creating "artificial endosymbionts" that could live inside some human body cells and do everything from helping regenerate damaged tissues to treating cancer.

"That's the vision in the long run," says Christopher Contag at Michigan State University.

Several other groups are also developing artificial endosymbionts, which they say could allow us to make crops and farm animals more productive, or treat age-related conditions.

The idea of creating artificial endosymbionts used to be regarded as fanciful, says Bogumil Karas at the University of Western Ontario in Canada, but due to advances in our ability to engineer organisms in recent years, it is starting to be seen as feasible.

"This is going to be one of the biggest things in the very near future," he says.

> "It is amazing the team managed to get the bacteria into such a high proportion of the cells"

Some bacteria have naturally evolved to live inside the cells of plants or animals in a mutually beneficial relationship called endosymbiosis.

Endosymbionts can give organisms abilities vital for their survival. The energy-producing structures in all animal and plant cells evolved from endosymbiotic bacteria, for example.

To create a new endosymbiont from scratch, Contag's team started with a bacterium called *Bacillus subtilis*, found in our guts among other places.

The researchers engineered it to produce mammalian proteins that alter the activity of genes and thus control what mammalian cells do.

To get the bacteria inside mouse cells, Contag's team relied on the fact that some animal cells can engulf bacteria via a process called phagocytosis. Normally, engulfed bacteria remain trapped in membrane-bound sacs where they are digested. But the engineered *B. subtilis* strain secretes a protein that enables it to break out of these sacs.

The researchers added the engineered bacteria to mouse immune cells known as macrophages growing in a dish. They managed to get the bacteria into 99 per cent of cells. They also showed that the mammalian proteins the bacteria had been engineered to produce altered the behaviour of the macrophages (bioRxiv, doi.org/g359).

Right now, the bacteria divide quickly and kill the macrophages after a few days, so there is more to be done to make the system work, say the researchers.

Even so, it is amazing the team managed to get the bacteria into such a high proportion of cells, says Karas. However, achieving this in the body will be much more difficult, he says.

John Rasko at the University of Sydney cautions that even if it is possible, there will be significant regulatory hurdles to navigate before the technology could ever be used in people. ▮

Space exploration

Tardigrades could survive interstellar space travel

THE first interstellar travellers from Earth may be a species that is no stranger to space exploration: tardigrades. These creatures grow only 0.5 millimetres long but are some of the most resilient animals known to science, even surviving in the vacuum of space.

Until now, only five craft have travelled the 18 billion kilometres to interstellar space, each taking decades, but a NASA-funded research project is developing craft propelled by solar sails, boosted by Earth-based lasers, that could cover the distance in days. This opens the door to sending live organisms.

Stephen Lantin at the University of Florida and his colleagues analysed how much food would be needed to keep various species alive, how much they weigh and their resilience to the high levels of radiation and acceleration they would encounter on the journey. Tardigrades come out as a good option for low-maintenance, pioneering interstellar travellers (*Acta Astronautica*, doi.org/g353).

3DSTOCK/SHUTTERSTOCK

Tardigrades go into a form of low-energy hibernation to survive tough environments

"It would be nice to send humans, but there are some biological constraints that would make it more favourable for us to send other organisms, at least in the first few flights," says Lantin. "It takes a lot of energy to send anything out into interstellar space, at least at the speeds that we're proposing." To do that, you need a small payload, he says, and, unfortunately, it would be a one-way mission.

Tardigrades and the roundworm *Caenorhabditis elegans*, another species in contention, both have the benefit of being capable of cryptobiosis, a form of extreme hibernation in which the animals radically slow their metabolism when in adverse conditions such as desiccation or freezing.

Tardigrades are thought to use just 0.01 per cent of their normal energy when in cryptobiosis. They have already been shown to survive space flight and exposure to the vacuum of space on prior missions, and may have made it to the moon as part of a failed Israeli mission. ▮

Matthew Sparkes

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Social media

YouTube algorithm stopped harmful videos spreading

Chris Stokel-Walker

A POLICY change by YouTube to limit the spread of harmful videos has had the desired effect.

In January 2019, YouTube said it would no longer suggest what it deemed to be harmful videos through its recommendation algorithm, although it still allowed those videos to be stored on its website. Cody Buntain at the New Jersey Institute of Technology and his co-authors were sceptical the approach would have much effect because links to YouTube are so ubiquitous across social media.

"I was actually surprised at the results we found," he says. He and his colleagues monitored shares of 920,000 videos over the eight months before and after the policy change.

The researchers looked at three types of content. Two are considered harmful by YouTube's policies: conspiracy videos and videos posted by a group of alt-right YouTubers called the Alternative Influence Network (AIN), identified by the Data & Society Research Network in New York in 2018. The final type was a control group of videos from mainstream news channels. They analysed 827 million tweets and 79 million Reddit posts to see how many included these videos. Facebook wasn't included because of issues accessing the data – a limitation the authors acknowledge.

Conspiracy videos known to have been subject to YouTube's move saw a drop in how many times they were shared on Twitter and Reddit, as did videos from the AIN.

Mainstream news channel videos saw an increase in shares outside YouTube – indicating that the policy change worked (*Proceedings of the ACM on Human-Computer Interaction*, doi.org/g34j). However, less overtly harmful conspiracy videos not targeted by YouTube saw an increase in reach off the platform. ▮

Diseases

Covid-19 measures mean zero measles in Australia

Alice Klein

ROBERT WALLACE/WALLACE MEDIA NETWORK/ALAMY

Australian airports have been empty due to travel restrictions

NOT a single case of measles has been recorded in Australia this year, a side benefit of the country shutting its borders to keep out the coronavirus. Measles rates have also plummeted in most other nations, but experts are worried that interrupted immunisation programmes during the crisis could lead to a resurgence.

Before the covid-19 pandemic, measles infections in Australia had been climbing in line with global trends. In 2019, the nation recorded 284 cases – the most in five years. The majority were found in people who caught the virus overseas and brought it home.

Then, in March 2020, Australia introduced tight border controls to try to hold covid-19 at bay. Citizens have since been unable to travel overseas, non-Australians have been barred from entrance and all returning Australians have had to quarantine upon arrival.

During this time, there has been a sharp drop in measles infections in Australia, with just 25 cases recorded in 2020 and none so far in 2021. Fully vaccinated Australian citizens and permanent residents have been allowed to leave the country since 1 November.

While the border has been closed, any existing measles virus in Australia has "burnt itself out" thanks to high vaccination coverage and no more has been able to come in, says David Durrheim at the University of Newcastle in Australia. More than 94 per cent of Australian children are immunised against the disease.

94%

of Australian children are vaccinated against measles

Measles rates also seem to have waned in most other countries, although this is partly due to under-reporting by health systems that are busy dealing with covid-19, says Kim Mulholland, a member of the World Health Organization's working group on measles and rubella vaccines who is based in Melbourne.

Fewer than 5000 measles cases are currently being recorded per month worldwide, compared with more than 100,000 per month during the peak of the last big measles outbreak in 2019.

In England, there were two confirmed measles cases from January to September 2021, according to figures due to be released at the end of November, compared with 797 in the whole of 2019. In the US, there have been 45 cases in 2021 so far, down from 1282 in 2019.

This downwards trend has probably been driven by reduced travel and limited social contact during the pandemic, as well as the natural boom-and-bust cycle of measles, says Mulholland.

However, it may not last long since the pandemic has also interrupted many immunisation programmes around the world, with an estimated 27 million children missing out on getting the measles vaccine in 2020. "We've got a big and growing immunity gap globally, so the conditions are perfect for a post-pandemic measles catastrophe," says Durrheim.

"It's an accident waiting to happen," says Mulholland. Outbreaks of measles have already sprung up in countries like Pakistan, Nigeria, India, Afghanistan, Somalia and the Democratic Republic of the Congo, and these could spread to other nations as international travel rebounds, he says. ▮

genesis 2021

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NASA/JPL

Solar system

Jupiter's Great Red Spot is far deeper than we realised

JUPITER's Great Red Spot, the colossal storm that has raged in the planet's atmosphere for centuries, is even deeper than we expected.

NASA's Juno spacecraft, which has been orbiting the planet since 2016, used microwave readings and measurements of the density of material inside Jupiter to peer deep under its clouds. "This is the deepest look we've had into a giant planet," says Juno team leader Scott Bolton at the Southwest Research Institute in Texas. "Prior to this, we've just seen skin-deep."

The measurements showed that the Great Red Spot extends far beneath the planet's clouds, which sit about 240 kilometres below the top of the atmosphere, with the storm perhaps reaching a depth of 500 kilometres. Two smaller storms were found to have roots hundreds of kilometres deep, and the jet streams that make up the bands of colour at the top of Jupiter's atmosphere extend as deep as 3000 kilometres (*Science*, doi.org/g35w).

Researchers expected these depths to be fairly homogeneous. "Generally, the idea is that once you drop below where the sunlight reaches, below where the water condenses into clouds, it's all vapour," says Bolton. "Most people expected that it would be well mixed, so you wouldn't get much weather going on down there."

The fact that the roots of Jupiter's storms go so deep indicates that the layers of the planet's atmosphere are interconnected. "In hindsight, it makes sense that the layers are not completely isolated from each other, because it's a giant ball of gas," says Bolton. **Leah Crane**

Genetics

DNA of Sitting Bull matched to relative

A STUDY that blends history with DNA technology has further strengthened the claim of a familial relationship between a living Native American and a historical figure: Tatanka Iyotake, popularly known as Sitting Bull.

Sitting Bull was a leader of the Hunkpapa Lakota Sioux people. In 1876, he defeated General Custer's 7th Cavalry Regiment of the US Army in the Battle of the Little Bighorn, also known as the Battle of the Greasy Grass.

Today, Ernie LaPointe, a Native American author and president of the Sitting Bull Family Foundation, is widely accepted as the great-grandson of Sitting Bull. Now, LaPointe, who is named as a co-author on the study, has had his claim strengthened by genetics.

In 2007, a lock of Sitting Bull's hair at the National Museum of Natural History in Washington DC was repatriated to LaPointe and his sisters. A sample was sent to a team of geneticists led by Eske Willerslev at the University of Copenhagen for DNA analysis.

By comparing DNA from Sitting Bull's hair with DNA from LaPointe's saliva, the new study irrefutably establishes that LaPointe is the great-grandson of Sitting Bull, says Willerslev.

He says the methods generally used to establish ancestry weren't possible as the DNA in the hair was so degraded. But it was possible to use haplotype frequency to establish a relationship (*Science Advances*, doi.org/g352). A haplotype is a set of gene variants inherited from one parent.

Oglala Lakota Nation President Kevin Killer welcomes the research, which lends support to the culture of oral history of Indigenous people. "To see [our oral history] backed up by science... is a step in proving how strong our oral history that dates back to 10,000 years [is]." **Alakananda Dasgupta**

Coronavirus

Skin patch created for covid-19 vaccine

A SKIN patch for giving covid-19 vaccines provides greater immune protection than injections, according to a study in mice. The patch, pictured, can be stored at room temperature and be self-administered, making it suitable for use in places that lack cold storage facilities and medical staff.

David Muller at the University of Queensland in Brisbane, Australia, and his colleagues have developed a centimetre-wide skin patch dotted with 5000 plastic spikes, each a quarter of a millimetre long and coated with dried vaccine that is more stable than liquid forms. An applicator presses the vaccine into the upper layer of the skin.

DAVID MULLER/UNIVERSITY OF QUEENSLAND

Vaccines delivered this way tend to elicit stronger immune responses because the skin is full of immune cells, says Muller.

The researchers tested the patch with a covid-19 vaccine candidate called HexaPro, which is still being tested in clinical trials but is more heat stable and cheaper to make than existing vaccines.

Mice treated with the patch developed more coronavirus antibodies than those injected with the vaccine and were completely protected from getting sick, even with a single dose (*Science Advances*, DOI: 10.1126/sciadv.abj8065).

A trial of the covid-19 vaccine skin patch in people will begin next year. **Alice Klein**

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Really brief

SUZI ESZTERHAS/NATUREPL.COM

Panda's coat acts as great camouflage

The distinctive black-and-white coat of the giant panda helps the bears hide. When images of pandas in forests were fed through a program that simulates the visual system of predatory cats, the pandas were difficult to spot, particularly if they were tens of metres away (*Scientific Reports*, doi.org/g35r).

'5D' storage beats Blu-ray technology

A method of writing on glass could squeeze 500 terabytes onto a single disc – 10,000 times more data than fits on a Blu-ray disc. Dubbed 5D storage, it writes data using two dimensions of laser light – based on intensity and polarisation – and three spatial dimensions (*Optica*, doi.org/g35s).

Unowned cats in UK number 250,000

With the help of residents in five UK towns, an estimate has been put on the number of lost, abandoned and feral cats living in UK urban centres. Knowing there are potentially 250,000 of them will help authorities monitor the population in the years ahead (*Scientific Reports*, doi.org/g35v).

Particle physics

Physicists fail to find sterile neutrino

THE hunt for mysterious theoretical particles known as sterile neutrinos has turned up empty again.

Neutrinos are subatomic particles that barely interact with regular matter. There are three known types and the search for a fourth, called sterile neutrinos, has been going on for decades. These get their name because, unlike the other three types, they would only interact via gravity.

Because neutrinos are so small and interact so weakly with other matter, we can only observe them indirectly, via the products of collisions between other particles.

Two neutrino experiments have previously found more of these products than expected. However, neither could tell the difference between electrons and photons in its results – and sterile neutrinos would only produce extra electrons. An experiment called MicroBooNE at the Fermi National Accelerator Laboratory in Illinois can tell the difference, but its first three years of data show no extra neutrino products.

"I would have expected to see an excess in either the photons or the electrons and we haven't seen one in either, which opens up more questions," says MicroBooNE spokesperson Justin Evans at the University of Manchester, UK.

Is the hunt over? "We definitely are not seeing any evidence for a sterile neutrino," says Evans. "As to whether it is completely dead, I think that depends who you ask, but you've certainly got to get a lot more inventive to get a sterile neutrino into your particle physics models now." **LC**

Zoology

TONY HARRINGTON/STOCKSHOT/ALAMY

Why sharks may mistake surfers for seals and sea lions

HUMANS and seals look remarkably similar in the water from a great white shark's perspective, adding evidence to the idea that shark bites on humans may be a case of mistaken identity.

Although shark bites on humans are extremely rare, they cause a significant and disproportionate amount of public concern.

Laura Ryan at Macquarie University in Australia and her colleagues made video recordings of a seal and a sea lion swimming in tanks, and also recorded people swimming and paddling on a surfboard in a tank.

To assess the visual similarity from the perspective of juvenile great whites, which are responsible for the majority of shark bites, the team analysed the recordings using a model of the sharks' visual system, taking into account their colour blindness and inability to see detail.

The researchers found that the sharks would see little difference between the motion of humans swimming, humans paddling on surfboards and seals and sea lions swimming. They also found that seals and sea lions with their fins out looked similar in shape to human swimmers and surfers (*Journal of the Royal Society Interface*, doi.org/g35z). **Chen Ly**

Ornithology

Birds have a taste for truffles

BIRDS have been found to eat truffles – fungal fruiting bodies that were assumed to be eaten only by mammals. The discovery, in the Patagonian region of South America, suggests birds in this area play an important role in the dispersal of truffle spores.

Matthew Smith at the University of Florida and his colleagues collected 169 bird faecal samples mainly belonging to two bird species, the chucao tapaculo (*Scelorchilus rubecula*) and the black-throated huet-huet (*Pteroptochos tarnii*). The researchers collected the samples in Patagonia in 2018 and 2019. They then used DNA analysis to identify truffle spores in the samples, as well as fluorescence microscopy to see whether the spores were intact.

They found truffle spores in 42 per cent of chucao tapaculo and 30 per cent of black-throated huet-huet samples. Many of the spores in the faecal samples were intact, which means they were still viable (*Current Biology*, doi.org/g354).

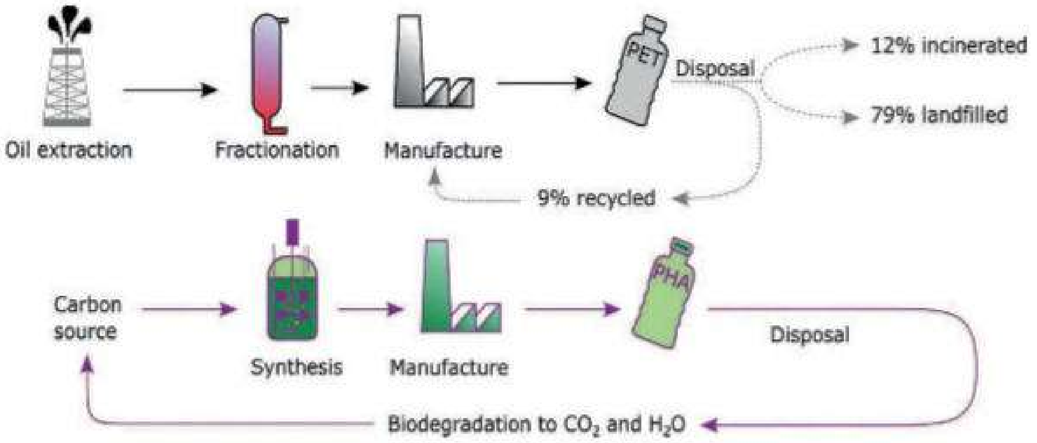
The findings suggest that birds play a large role in spreading truffles to new areas throughout the forests of Patagonia. They also imply that fungi are a big part of these birds' diets. **CL**

Bioplastics: A sustainable alternative to plastics

Victor Irorere and Callum McGregor: SBRC – Nottingham

From mobile phones to clothing, plastics have become an integral part of our lives. Their low cost, ease of manufacture, durability and wide range of applications has led to a steady increase in plastic production, with over 370 million tonnes produced in 2019. More than 99% of plastics are derived from fossil resources, the reserves of which are rapidly depleting. Additionally, fossil-based plastics e.g., the commonly used polyethylene terephthalate (PET) are not biodegradable or readily recyclable, causing significant environmental damage. As such, alternative materials are needed, which are either biodegradable and/or recyclable, and can be produced from renewable resources. This is where bio-based plastics or "bioplastics" such as polyhydroxyalkanoates (PHAs) can step in [Fig. 1].

Fig. 1 Comparison of life cycles between traditional plastics and PHAs



Discovered in 1926 by French researcher Maurice Lemoigne, PHAs possess properties like those of traditional fossil-based plastics with additional advantages of being biodegradable, non-toxic, recyclable and obtainable from renewable sources. There are many types of PHAs based on their structure, allowing a wide range of material applications. PHAs could replace single-use plastics such as packaging and plastic utensils and in agriculture as mulch film bags. In medicine, PHAs have been used as biodegradable sutures, drug delivery capsules and tissue scaffolds for use in regenerative medicine. Current research has a strong focus on making the production of PHAs cheaper by using waste carbon sources and altering the properties of the PHAs to better replicate those of traditional plastics.

SBRC-NOTTINGHAM is a UKRI BBSRC/EPSRC funded, Synthetic Biology Research Centre led by Professor Nigel P. Minton at the University of Nottingham, UK. SBRC–Nottingham aims to provide new technologies in the form of engineered bacteria and processes that together can be used at scale by industry to transform our energy intensive economy into a sustainable and more carbon neutral bioeconomy. The Centre is collaborating with industry to optimise and commercialise the production of low carbon fuels and everyday chemicals using gas fermentation.

For more information visit:
https://sbrc-nottingham.ac.uk/

SynBio
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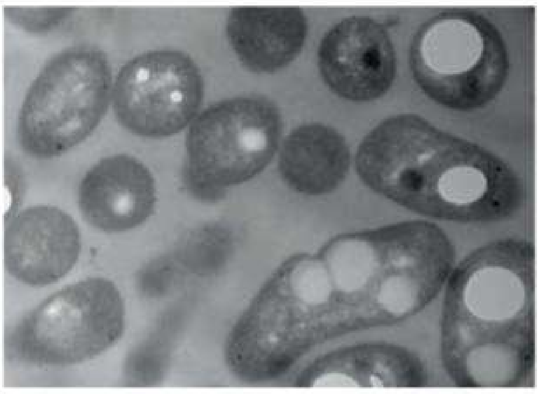
PHAs are naturally produced by various species of bacteria. While these bacteria save the PHAs for use as an energy source, they can be extracted from bacteria and processed in much the same way as traditional plastics. Bacteria can produce PHAs from a range of carbon sources, from sugars to waste gases such as carbon dioxide (CO_2). PHAs biodegrade to form CO_2 and water (H_2O), which can be reused to make new PHAs directly by certain gas-fermenting bacteria, such as *Cupriavidus* spp. [Fig. 2]. These bacteria allow renewable production of plastics from waste compounds without the need for fossil resources. Additionally, the biodegradability of PHAs reduces the environmental damage associated with traditional plastics.

Fig. 2 Electron micrograph showing PHA granules in Cupriavidus spp.



About us

*With a PhD in Microbial Biotechnology and Biochemistry, **Victor Irorere's** research mainly focuses on optimising the production of sustainable and green platform chemicals. He joined SBRC in 2019 as a Research Fellow, working on upstream process development for the biosynthesis of a range of chemicals with focus on Bioplastics from C1 gases. He has over 16 publications and in the future plans to work with industries to develop processes for bioproduct manufacturing that minimises waste and optimise productivity.*

***Callum McGregor** completed his PhD at SBRC-Nottingham, in which he worked on the production of biodegradable plastics using bacteria. His research now focuses on the metabolic engineering of bacteria for the sustainable production of chemicals and polymers from C1 gases.*

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Comment

Musk's millions

Financially speaking, Tesla is a massive success. The question is what will it do with all that money, says **Rowan Hooper**

MICHELLE D'URBANO

WHEN Elon Musk joined the fledgling car firm Tesla in 2004, he put in \$6.5 million to become majority shareholder and chair of the board. Seventeen years later, in October this year, the firm reached a market value of \$1 trillion, only the sixth US company to do so, and the second-fastest, after Facebook.

While much talk in financial circles concerns the company's balance sheet – it is the lowest-revenue business to achieve a \$1 trillion valuation – I am more interested in what comes next and how it encourages rapid change towards a greener future.

Musk has long been clear that the ambition for Tesla isn't just about building electric cars, but about disrupting the entire economy.

Tesla is a major manufacturer and installer of photovoltaics in the US, with plans for expanded production of solar panels and roof tiles. You can imagine the corporate vision is one where every house has a Tesla solar roof feeding a Tesla electric vehicle parked outside. The company is already one of the largest manufacturers of batteries and energy storage systems at scales ranging from vehicles to homes to entire grids.

So what's next? It would be great if Musk could make heat pumps sexy, though even he might struggle with that. Perhaps a different approach would be to wrap it all up as a net-zero housing offering. The TeslaHouse? I would live in it – if I could afford it.

I had an interaction with Musk that gives me a clue as to where else the company might go. Just before my book *How to Spend a Trillion Dollars* came out this year, I sent Musk a copy in the hope he might provide a blurb for the cover. He said he would read it. When I prodded him a bit later, he responded, "Is that the book with [Amazon founder Jeff] Bezos in it?" and then I heard nothing more. Well, he is a busy man. But then a few months later, something strange happened.

My book is about the global and scientific problems you could solve, or at least tackle, if you had huge funds at your disposal. In one chapter, I look at the problem of getting carbon dioxide out of the atmosphere and suggest that a good way to stimulate the development of technology to do this at scale would be to launch a lucrative competition. I propose a prize of \$100 million to the first group able to remove and bury 100,000 tonnes of CO_2, or to remove 1 tonne of CO_2 for \$200.

After being sent my book, Musk announced he was launching the XPrize Carbon Removal – with a prize of \$100 million. Even if it isn't strictly true, it is nice to say that I spent \$100 million of Musk's money.

So why is Musk so interested in CO_2 removal? Well, it currently costs about \$600 to capture 1 tonne of CO_2. Once the price comes down, you can imagine the demand there will be from firms and individuals to pay to offset their carbon emissions. You can imagine the size of the future market. Scaling up production of carbon-capture units will be a multibillion-dollar industry.

We mustn't forget Mars. A lot of what Musk does is directed towards the bigger goal of settling on that planet. The atmosphere of Mars is about 95 per cent CO_2 and a device that can efficiently remove it from the air will be useful for making food and fuel.

You might not agree that settling on Mars while our own planet is in such terrible shape is a worthy thing to do, and you might be uncomfortable or even repelled by claims about Musk's behaviour or the terms of employment for his staff or the amount of tax he has or hasn't paid. That isn't the point here.

The point is that his strategy has worked. I hope that Tesla's trillion-dollar valuation spurs the company to roll out more green solutions on Earth and inspires new start-ups to do the same. ▮

Rowan Hooper is podcast editor for *New Scientist*. His latest book is *How to Spend a Trillion Dollars*

#FactsMatter

Are we really addicted to fertiliser?

Frequent reports decrying our ever-increasing use of synthetic fertilisers don't reflect reality and fail to see the bigger picture, writes **James Wong**

James Wong is a botanist and science writer, with a particular interest in food crops, conservation and the environment. Trained at the Royal Botanic Gardens, Kew, he shares his tiny London flat with more than 500 houseplants. You can follow him on Twitter and Instagram @botanygeek

THE interconnectivity of our world never fails to amaze me. Even as a plant scientist fascinated by food production, I am often astonished by the extent to which changes in a seemingly unrelated industry on a distant part of the planet can affect our dinner plates – and the reaction of pundits to these impacts.

Recently, news broke that soaring global fertiliser costs, created by factors such as rising energy prices in China, would be likely to have a devastating knock-on effect on the food security of some of the poorest people on Earth.

Surprisingly, some activists and thought leaders saw this price hike as a good thing, because it would provide a market mechanism to force farmers to reduce their "addiction" to fertilisers. According to this narrative, fertiliser use has gone "up and up", and masked a "terrifying and accelerating" collapse in global soil health, which is often worse for people in low-income countries trying to feed themselves. Given the frequency and conviction with which this view is expressed, and the devastating impact it could have, I thought I should go in search of the facts.

So, the first thing we need to acknowledge is that overuse of fertiliser is a problem. It is well established that run-off of excess nutrients pollutes water courses, with a destructive impact on the environment. The extent of this effect can be wide-ranging, with farmland run-off in the US Midwest contributing to algal blooms in the Gulf of Mexico hundreds, sometimes thousands, of kilometres away.

That is before we talk about the greenhouse gas emissions produced in the manufacture of fertiliser. Alone, the Haber-Bosch process – which captures atmospheric nitrogen and converts it into a soluble form that plants can more readily use – produces roughly 1.4 per cent of global carbon dioxide emissions. That might sound like a small amount until you compare it with the emissions associated with all of the aviation industry, which are around 2 per cent.

I think we can all agree that reducing our reliance on such synthetic fertilisers would be a good thing. But this is where it starts to get complicated. Despite frequent reports of ever-escalating use of synthetic fertiliser, in fact, in many Western countries, it has markedly declined.

> **"In the UK, the amount of fertiliser used per hectare has fallen by about 20 per cent since the millennium"**

In the UK, for example, the amount of fertiliser used per hectare has fallen by about 20 per cent since the turn of the millennium, and is now at its lowest levels for more than 30 years. Many other European countries, including the Netherlands, Italy and Denmark, have seen a similar trajectory, as has Japan. Even when you include some of the world's most important food-producing countries such as the US, Russia and Australia, you see a plateauing of fertiliser use over the past two decades, certainly not the unstoppable upwards trajectory that is often claimed.

What is true, however, is that on a global level, there has been a big increase in the use of fertilisers in the same period, with a 32 per cent rise recorded since 2002.

Even this, though, doesn't really show us the complete picture. Fertiliser usage is traditionally calculated by the weight used per unit of land. Given that the whole point of the exercise is to feed people, would it not make more sense to see these stats in the context of global population levels? After all, while global land area hasn't changed in the past two decades, our population has increased by around 27 per cent.

Use of synthetic fertiliser broadly reflects an increase in the number of mouths to feed. In fact, some scientists have calculated that since its widespread adoption at the beginning of the 20th century, it has been the only way we have been able to support a growing population. Two decades ago, these fertilisers allowed us to feed 43 per cent of humanity. By 2015, that figure was estimated to have increased to just under half the world's population.

Here is some more context: today, as many as 811 million people go hungry. In fact, after decades of progress, the number of people lacking access to sufficient food is on the rise again, growing by as many as 161 million between 2019 and 2020 alone. Severe food insecurity now affects just under 1 in 10 people.

So, yes, we do need to reduce our reliance on fertiliser use, and many of the world's advanced economies have already taken great strides to do that. However, there is no solid evidence to support the claim that fertiliser use is dramatically rising, particularly in the context of countries like the UK. And, crucially, taking into account the human cost, the argument that fertiliser price rises are in some way beneficial to humanity is one that can be made only with the luxury of a full belly. ▮

James's week

What I'm reading

In an effort to create some semblance of a work-life balance, my reading has been confined to pub and restaurant menus.

What I'm watching

Am I the only person not watching Squid Game*? So far this month, it has been a* Frasier *marathon.*

What I'm working on

I am finishing up making a global farming series for the BBC as I type.

This column appears monthly. Up next week: Chandra Prescod-Weinstein

POSTGRADUATE AND/OR GRADUATE CHEMIST FOR CONSULTANT POSITION

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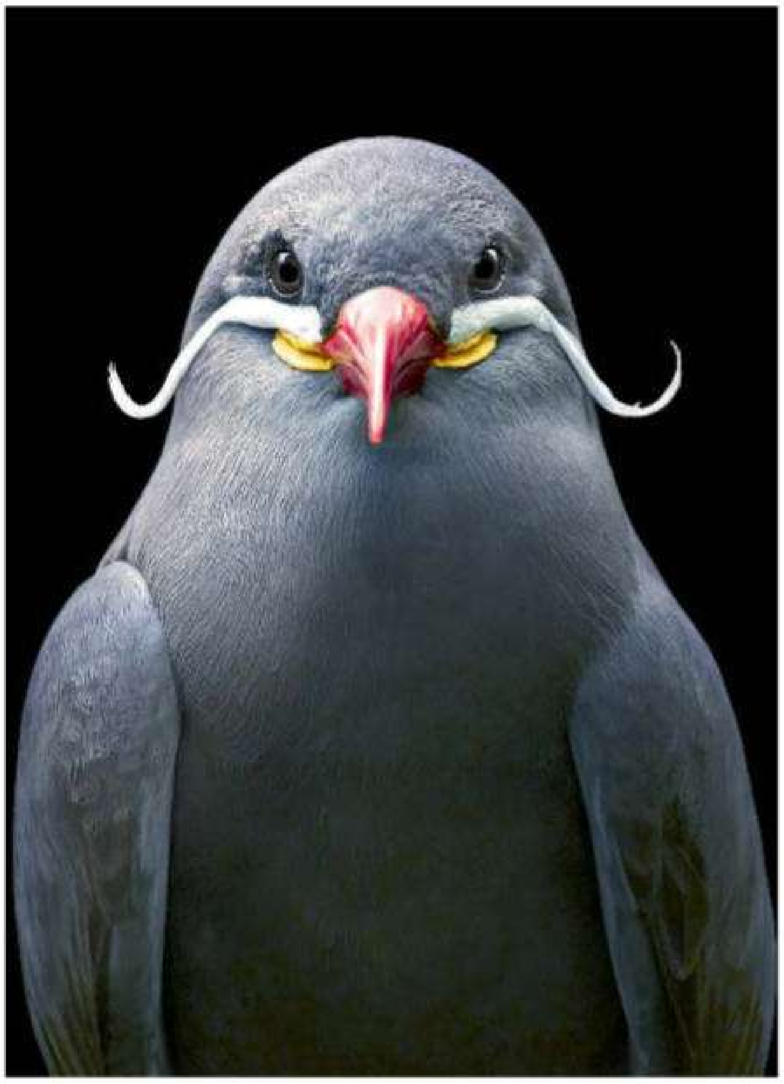


Glorious birds

Photographer Tim Flach

MAJESTIC and intricate, these stunning images showcasing the diversity of birdlife are taken from *Birds*, a photography book by Tim Flach.

A toco toucan (*Ramphastos toco*) displays its distinctive bright bill in the main image. The largest and best-known of the toucans, this species is found in tropical forests, savannahs and shrubland in parts of South America. Its large-but-light bill, which can reach up to 19 centimetres in length, is adapted for grabbing a variety of food, including fruit and insects.

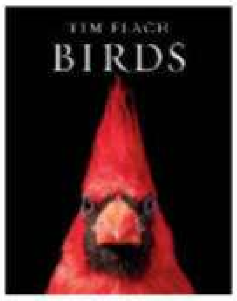
The top-right photo is of a group of American flamingos (*Phoenicopterus ruber*), collectively known as a flamboyance. The uniquely shaped bills of these filter-feeders allow them to eat while their heads are upside down under the water.

The bottom-middle image shows the elaborate plumage of a male Mandarin duck (*Aix galericulata*), a native of east Asia and Russia that has also been introduced to the UK.

The distinctive "moustache" of an Inca tern (*Larosterna inca*), bottom right, highlights the variety of displays birds use to attract mates. For Inca terns, long moustaches are believed to indicate better health and a strong immune system. Eat your heart out, Hercule Poirot.

Birds will be published by Abrams on 11 November.

Gege Li



Editor's pick

How the news of feathered dinosaurs lifted off

16 October, p 43

From Jeff Hecht,
Auburndale, Massachusetts, US

As the reporter who broke the story of the discovery of feathered dinosaurs, I enjoyed Michael Benton's feature. It was in fact *New Scientist* that carried my story, just before the work was unveiled at the Society of Vertebrate Paleontology meeting at the American Museum of Natural History in New York.

Before the meeting, I picked up reports of a surprising discovery in China. After some detective work, a contact told me it was "a little feathered dinosaur". I persuaded the news editor to squeeze it into the upcoming issue. To follow up, I took the train from Boston to New York and slept on my sister's couch in the suburbs so I could attend the meeting. I then went on to write about palaeontologists travelling to China to see the feathered fossil.

This was one of the most exciting stories I have covered, one that revolutionised our understanding of dinosaurs and birds.

Children are natural scientists until school

16 October, p 36

From Sam Edge,
Ringwood, Hampshire, UK

From your review of *Ada Twist, Scientist*, I am looking forward to seeing it. However, it occurred to me that young children don't need to be encouraged to be scientists.

My granddaughter's second birthday is coming up and she has been engaging in increasingly sophisticated experimental investigations since she was old enough to hold things.

My impression is that, in pursuit of government league table success, UK schools educate scientific curiosity out of children because it is incompatible with the inflexible, one-way nature of the national curriculum.

According to the increasingly disillusioned teachers with whom I have discussed this, even science subjects are taught as a set of handed-down facts to learn so as to pass the exams, not as a framework of knowledge with which to ask questions.

Recycling systems need to cover much more

25 September, p 18

From Graham Jones,
Bridgham, Norfolk, UK

Regarding the debate over a bin tax to encourage recycling, we need systems that can deal with many kinds of waste. There is already one for anaerobic digestion of all organic matter: the sewage treatment system. In principle, the methane it produces could be fed into the grid and help reduce the currently rising price of gas. If it could take kitchen and garden waste; agricultural waste, such as straw and manure; culled animals; building waste, such as cardboard and wood; and even human cadavers, then the amount of methane generated might be significant and useful.

A paradoxical problem in the black hole paradox

25 September, p 34

From Frank Scott, Sydney, Australia

In his article on the black hole information paradox, Paul Davies postulates a "residual connection reaching across the event horizon" between entangled pairs of particles of Hawking radiation. One particle travels back across the event horizon of the black hole, and the other travels away.

With one of the pair moving towards intense gravity and the other away from it, wouldn't the entanglement be immediately broken by the disparity in the passage of time experienced by each particle?

If their entanglement isn't broken, what effect would synchronising between different timescales have on the particles' information ?

Not quite time for AI to show human-like skills

Letters, 23 October

Eric Kvaalen,
Les Essarts-le-Roi, France

Robert Checchio writes that "the GPT-3 AI discussed in your article is reported to have 175 billion artificial neurons (twice that of a human brain)" and so some might expect human-like behaviour to appear soon. But in your feature (9 October), you said 175 billion parameters, not neurons, roughly equivalent to the number of synapses. You also indicate that the human brain has "150 trillion" synapses, meaning GPT-3 is nearly a thousand times smaller.

The promise of eradicating Lyme disease

16 October, p 24

From Stephanie Woodcock,
Truro, Cornwall, UK

A reliably safe and effective treatment for Lyme disease in humans would be a prize indeed. If hygromycin A were to live up to its early promise and become a medicine for acute Lyme disease, it would not only be a welcome development for new patients, but it might also have implications for established patients because it might provide a double-check on the current diagnostic system.

An estimated 10 per cent of people with Lyme disease report continuing ill health in spite of treatment and can be subject to having their Lyme diagnosis questioned (6 June 2020, p 40). If research goes as hoped and a medicine results, a humane way of proceeding might be to offer people with a Lyme or Lyme-like symptomatology an exploratory round of the new treatment. Given that diagnosis status still largely relies on blood tests, which don't seem completely reliable, this would be a chance to learn more about the needs of these patients.

However, such spirochaetal diseases should be treated as early as possible for the best outcome. Trying a treatment after time had elapsed would be a voyage into the unknown for longer-term patients and it would be better not to raise unrealistic hopes.

It is time to forget about repressed memories

9 October, p 44

From Annie Campbell,
Lane End, Buckinghamshire, UK

I am grateful to Jessica Hamzelou for her insightful article on repressed memory, or dissociative amnesia as it is now termed. Whatever it is called, it has led to many vulnerable people being let down by those they sought help from, causing great damage.

After qualifying as a psychologist in 2000, I was appalled at the seeming obsession of some fully trained professional therapists or counsellors about abuse and their assumption that it was likely to have occurred, with no evidence of this being the case.

There is a condition called transient global amnesia in which a traumatic event isn't stored by the brain at all, thus no amount of therapy could "retrieve" it, but no scientific evidence that detailed traumatic memories are hidden away and can be revealed later by a therapist. I hope this article helps to put a stop to the continuing practice by some well-meaning though misguided professionals and that dissociative amnesia is finally removed from diagnostic manuals. ▮

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It's a (hu)man's world

We have made an indelible mark on the planet and the species we share it with. But our future impacts may be even greater, finds **Gege Li**

Book
Life As We Made It
Beth Shapiro
Oneworld

LOOK around you, and the results of humanity's time on Earth are plain to see. Our species has been changing and refining the environment for generations. Landscapes and habitats that we take for granted as "natural" would look and behave very differently if humans hadn't come on the scene – and that's before you factor in our effects on other species.

In *Life As We Made It*, Beth Shapiro, a professor of ecology and evolutionary biology at the University of California, Santa Cruz, explores the ways that humans have transformed the world around us. In doing so, we have taken the reins of not only our own evolution, but also that of many other species, for better or worse.

Shapiro travels back in time to when our ancestors first learned how to "break the rules" of nature and follows our environmental tinkering to the present day, where the rise of new biotechnologies is giving us more power and influence than ever before.

The first part of the book, "The Way It Is", looks at how we began figuring out ways to change our environment rather than letting it change us. At first, this was unintentional. But 50,000 years ago, we made a pivotal transition from existing alongside other species to becoming apex predators, then domesticators, farmers and innovators. This was an important shift because it let us direct our own evolutionary path. It meant that those who may not have survived previously could live long enough to pass on their genes.

This, says Shapiro, "is how we became different, unquestionably, from every other species that lives or has ever lived on Earth. This is what it means to be human."

She draws on a variety of influences to investigate this idea, from our ancestors' interactions with other hominins, such as Neanderthals, and mass extinctions throughout history that were probably caused at least partly by humans spreading across the planet, overturning ecosystems as we went.

The second part of the book, "The Way It Could Be", casts a spotlight on arguably the most significant point in human history so far: the advent of technologies that let us edit genomes directly. This has allowed us to engineer desired traits into organisms that benefit us, and has opened up unprecedented realms of possibility to reroute evolution as we please. With such methods, we have the power to edit out diseases, save endangered species from extinction, develop more sustainable materials, remove pollutants from oceans and much more besides. "With synthetic biology, we no longer have to remain within the bounds of what we can imagine," writes Shapiro.

> **"We probably shouldn't have free rein with new gene-editing technology – with it comes responsibility"**

We probably shouldn't allow ourselves free rein with this new technology – with it comes the responsibility to regulate the processes and resulting creations, and to decide when to use it, and whether it should be done at all.

TONY SAVINO/CORBIS VIA GETTY IMAGES

Some people dislike the idea of eating genetically modified foods

On this last point, Shapiro argues that decades of misinformation and sensationalism around genetically modified organisms, as well as fears of whether we should be "playing God", have led to public mistrust and unease. She calls this a "knee-jerk yuck factor" and says it is a significant barrier to realising the full potential of genetic engineering.

Shapiro makes a strong case that, given the pressing issues we face today – a growing global population, climate change and biodiversity loss – we will increasingly need to look to these tools if our species and others are to survive and thrive. "We can't both maintain the comfortable randomness of evolution and at the same time propel our world toward a defined future," she says.

While that is an undoubtedly important conversation, this is where *Life As We Made It* starts to stray slightly from its aim of exploring human innovation. For me, the book is most revealing when it considers how we have changed nature through the lens of our past interactions with other species, sometimes simply because we worked out how to breed different animals and plants to our advantage.

Nonetheless, the book provides a detailed exploration of some of the most influential technologies of our time. It also offers a tantalising glimpse of what might be in store in the future, when humanity starts to mix things up all over again. ▮

Gege Li is a freelance writer based in London

Who gets the water?

California's latest water war is one in which the winners and losers are all too predictable, finds **Katie Smith-Wong**

Film

River's End: California's latest water war

Jacob Morrison

Roco Films

HOME to more than 39 million people, California is the most populous US state. It is also among the driest. Together, these factors make demand for water a long-standing challenge. *River's End*, a new documentary by Jacob Morrison, dives deep into the water crisis and asks difficult questions about who gets the water and why.

At the centre of the film is the Sacramento-San Joaquin river delta, an estuary in the north of the state. Connecting the Sacramento and San Joaquin rivers, the delta is a key source of fresh water and the battleground for the latest California water war.

In 2015, then-governor Jerry Brown and the California Department of Water Resources proposed a $15 billion plan now known as California WaterFix & EcoRestore that would see two large tunnels built from the Sacramento river under the delta to provide water for California. Inevitably, not everyone agrees with the plan: the tunnels would redirect water towards southern California, reducing freshwater supplies to farmers around the delta.

Narrated by DeLanna Studi, *River's End* combines stock footage of landscapes around the delta and other parts of California, which highlights the fluctuating water supply levels, with simple animation to bring an educational slant and explain the extent and significance of the issue. With interviewees including politicians, corporate officials and local farmers, Morrison delivers a bleak yet brutally honest insight into the battle for water.

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MICHAEL MACOR/SAN FRANCISCO CHRONICLE VIA GETTY IMAGES

Some groups oppose the construction of two water tunnels in California

The documentary touches briefly on supply disputes in the early 20th century in the Owens valley and its role in the California water wars, which comprised a number of political conflicts between local farmers and the City of Los Angeles over water rights. But its main thrust examines how current supply issues are causing conflict between regional corporations and local farmers.

Both sides say they need water to run their businesses, but it soon becomes clear that the local communities don't have nearly as much government support as the corporations. There is testimony from frustrated local farmers who rely on water from the delta to grow their produce and say their livelihoods have been affected, not only by a lack of supply, but also by pumping facilities, which take water away from the area.

The situation in the Westlands Water District in central California proves particularly enlightening. Its connections with ex-President Donald Trump (via former Westlands lobbyist David Bernhardt), a focus on lucrative yet thirsty almond farming and the substantial difference in living conditions between farm owners and workers in the field paint a stark picture of the power and influence of large corporations.

Although the corporation-versus-the-little-person narrative is all too recognisable, the documentary also zooms out further to highlight the consequences on the wider environment and the wildlife that also relies on it for survival. Among the locally endangered species mentioned is the delta smelt, a fish species that is close to extinction due to the ongoing damage to the delta's ecosystem.

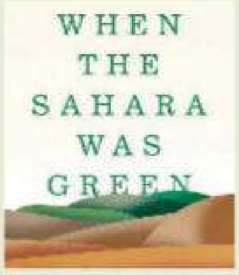
River's End provides a thorough overview of California's water issues and the need to achieve a sustainable water supply. It ends with a solemn message. As the state's population continues to grow, it remains unclear whether there will be enough water to meet the requirements of all those who need it. In the end, it may come down to who needs, or perhaps who wants, it more. ▮

Katie Smith-Wong is a film critic based in London

Don't miss

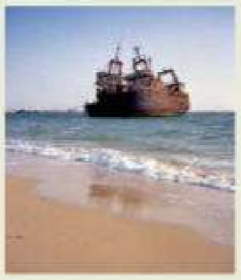
Watch

The Geology of Pluto, from its methane caps to its cryovolcanoes, is explored by Veronica Bray at the University of Arizona in this hour-long online talk, at 5pm GMT on 10 November from the Geological Society in London.



Read

When the Sahara Was Green it sustained turtles, crocodiles, hippos and prehistoric hunters. What turned this green and fertile land into the largest hot desert in the world? Australian earth scientist Martin Williams investigates.



Visit

We Are History at Somerset House in London uses art to explore the forgotten role of colonialism in the development of the current climate crisis. Curated by writer Ekow Eshun, the exhibition runs until 6 February.

TOP: NASA; LEFT: ZINEB SEDIRA, THE LOVERS II. COURTESY THE ARTIST & KAMEL MENNOUR, PARIS/LONDON

The film column

Butterflies without borders

Son of Monarchs is a beautiful film that explores themes of inspiration and belonging through the eyes of a brilliant young scientist with a tragic backstory, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on Instagram at @simon_ings

ALEJANDRO MEJÍA/WARNERMEDIA ONEFIFTY

Mendel (Tenoch Huerta) is a scientist who works in a New York lab

Film

Son of Monarchs

Alexis Gambis

In selected cinemas and on HBO Max

SOMETHING has gone wrong in Mendel's life. Bob, his boss at a genetics laboratory in New York City, is holding up a journal for his young post-doc to see. On the cover is a close-up of the wing of a monarch butterfly and a cover-line announcing the lab's breakthrough: they have shown how the evolution and development of butterfly colour and iridescence are controlled by a single master regulatory gene.

"This is you. Own it," says Bob (William Mapother). But Mendel (Tenoch Huerta, familiar from the Netflix series *Narcos: Mexico*) is close to tears.

Mendel is a man trapped between worlds who is no more comfortable in the lab than in the butterfly forests of Michoacán, Mexico, where he grew up.

Bit by bit, through touching flashbacks, some disposable dream sequences and one rather overwrought row, we learn the reasons why. We see how, when Mendel and his brother Simon were children, a mining accident drowned their parents; how their grandmother took them in, but things were never the same; how Simon went to work for the company responsible for the accident, and has ever since felt judged by his high-flying, science-whizz, citizen-of-nowhere brother.

When *Son of Monarchs* premiered at this year's Sundance Film Festival, critics picked up on its themes of borders and belonging, the harm walls do and the ways nature undermines them.

> **"This film isn't about scientific findings, but science as a vocation and how to relight the spark of curiosity"**

Mendel grew up in a forest alive with clouds of monarch butterflies. Sarah, his New York girlfriend (Alexia Rasmussen; note-perfect but somewhat under-used), is an amateur trapeze artist. The point – that flying creatures know no frontiers – is clear.

To underline this, a flashback shows Mendel and Simon in happier days, imagining a time when humans have evolved wings.

In a more scripted film, such gestures would have been heavy-handed. Here, though, they are pretty much all the viewer has to go on in what is sometimes a painfully indirect film.

The plot does come together through the character of Mendel's old friend Vicente (a stand-out performance by the relatively unknown Gabino Rodríguez). While muddling along like everyone else in the Mexican village of Angangueo, Vicente has been developing animistic rituals. His performances seem excessive at first – a young man's high spirits finding their eccentric expression – but as the film advances, we realise that these rituals are what Mendel needs. For him, Vicente's rituals offer an escape: a way to re-engage with the living world.

Son of Monarchs is, on one level, about identity, about how a cosmopolitan high-flier learns to be a good son of his home village. But it is also about belonging: about how Mendel learns to live both as a scientist and as a man lost among butterflies.

Film-maker Alexis Gambis is himself a biologist and founded the Imagine Science Film Festival. While *Son of Monarchs* is steeped in colour, and full of cinematographer Alejandro Mejía's mouth-watering and occasionally stomach-churning macro-photography of butterflies and their pupae, ultimately this isn't a film about the findings of science. It is about science as a vocation and how to relight the spark of curiosity. It is a hopeful film and, on more than the visual level, a beautiful one. ▮

Simon also recommends...

Books

Paper

John McCabe

Black Swan

The numbing futility of the bench scientist's life is sent up wonderfully in this tale of desperation, time-wasting and murder.

When We Cease to Understand the World

Benjamín Labatut

Pushkin Press

Shortlisted for this year's International Booker prize, this "factual novel" sees the founders of quantum mechanics struggle with the implications of their work.

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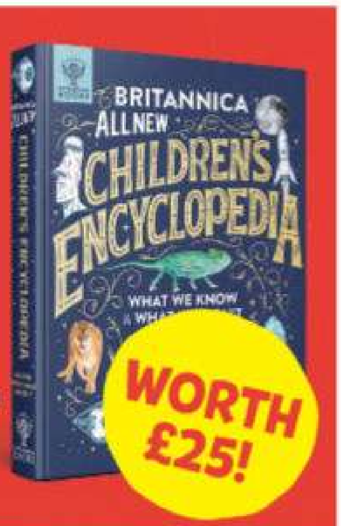

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Is reality real?

New experiments could be about to answer the most confounding quantum question of all, finds **Thomas Lewton**

CREDIT

THERE is an old philosophy question about a tree in a forest. If it falls with nobody there to hear it, does it make a sound? Ask a quantum physicist and they might say the sound was there – but you couldn't be sure the tree was.

Quantum mechanics has long pushed the boundaries of our understanding of reality at its tiniest. Countless experiments have shown that particles spread out like waves, for instance, or seem be in more than one place at once. In the quantum world, we can only know the likelihood that something will appear in one place or another – until we look, at which point it assumes a definite position. This troubled Albert Einstein. "I like to think that the moon is there even if I am not looking at it," he said.

Now, a new class of experiments is putting Einstein's conviction to the test, seeing if quantum weirdness stretches beyond the tiny world of quarks, atoms and qubits into the everyday world of tables, chairs and, well, moons. "If you can go from one atom to two atoms to three to four to five to a thousand, is there any reason why it stops?" says Jonathan Halliwell at Imperial College London.

These experiments are not just investigating whether there is a hard boundary between the quantum and classical worlds, but also probing the true nature of reality. If the work goes as some theorists expect, it might just kick the legs out from under one of our most firmly held beliefs: that things exist regardless of whether we are looking at them.

In 1935, Einstein came up with a thought experiment designed to reveal that quantum mechanics was an incomplete theory of reality that must, sooner or later, be replaced. Together with his colleagues Boris Podolsky and Nathan Rosen, he imagined a pair of particles entangled with each other so that whatever you do to one instantly affects the other. Measure, say, the position or velocity of one particle and it will reveal the position or velocity of the other without having to measure it. Now imagine placing these particles at opposite ends of the universe and performing the same measurement. At first glance, it seems that information is being transmitted between the particles faster than the speed of light.

OLENA SERGIENKO/UNSPLASH

Einstein argued that this "spooky action at a distance" was so absurd that the outcome of any entanglement experiments must be predetermined. Physicist John Bell was also uncomfortable with the ill-defined nature of quantum mechanics. In 1964, he devised a mathematical way to put this paradox to the test, called Bell's inequality. If Einstein and his colleagues were right, then Bell's inequality would be fulfilled.

Again and again, experiments have found that Bell's inequality is violated. If you insist that reality behaves classically, as opposed to in a quantum way, then to account for entanglement and the violation of Bell's inequality, "you have to assume that something happens faster than the speed of light", says Vlatko Vedral at the University of Oxford. Take your pick, Einstein: quantum weirdness is a reality or information breaks the universal cosmic speed limit.

But that is only part of the story. Bell's inequality addresses locality, the idea that the space between objects matters. It doesn't answer the question of whether the moon is there when you aren't looking. Realism says the position, speed, energy and other properties of particles can be reasonably well defined and performing a measurement on an object shouldn't affect what the object does in the future. Instead, quantum mechanics adds uncertainty and superpositions, mixtures of many possible identities that collapse into one value when a measurement is taken.

> "I like to think that the moon is there even if I am not looking at it"

Realism in macroscopic objects is called, you guessed it, macrorealism. When you look at the moon or measure how far away it is with a laser, you don't change it – at least, not according to our common-sense view of the world. "Macrorealism is the fullest expression of classical reality," says Halliwell. And, like Bell's inequality, there is a test for it.

Testing reality

The Leggett-Garg inequality, devised in 1985 by Anthony Leggett and Anupam Garg, also looks for correlations between measurements to see whether quantum or classical rules are being followed. But instead of two particles separated in space, like Bell's inequality, this deals with a single object over time. Because of this, Leggett and Garg realised they could, in theory, test the quantumness of very big objects. In other words, their inequality could tell us whether realism holds true in the everyday world.

In recent years, the first Leggett-Garg experiments have been carried out on simple quantum systems from superconducting fluids and photons to atomic nuclei and tiny crystals. These have demonstrated once again that the microscopic world is non-real. The trick with Leggett-Garg experiments is to make sure they are non-invasive, which means there needs to be a way of measuring a particle without disturbing it. That isn't easy, but it can be done. And in each case, the researchers found that for every non-invasive measurement they could make, the system was in a superposition of states.

Now, it is time to test something bigger. "It all boils down to seeing how far we can push this," says Urbasi Sinha at the Raman Research Institute in India. "We don't really know."

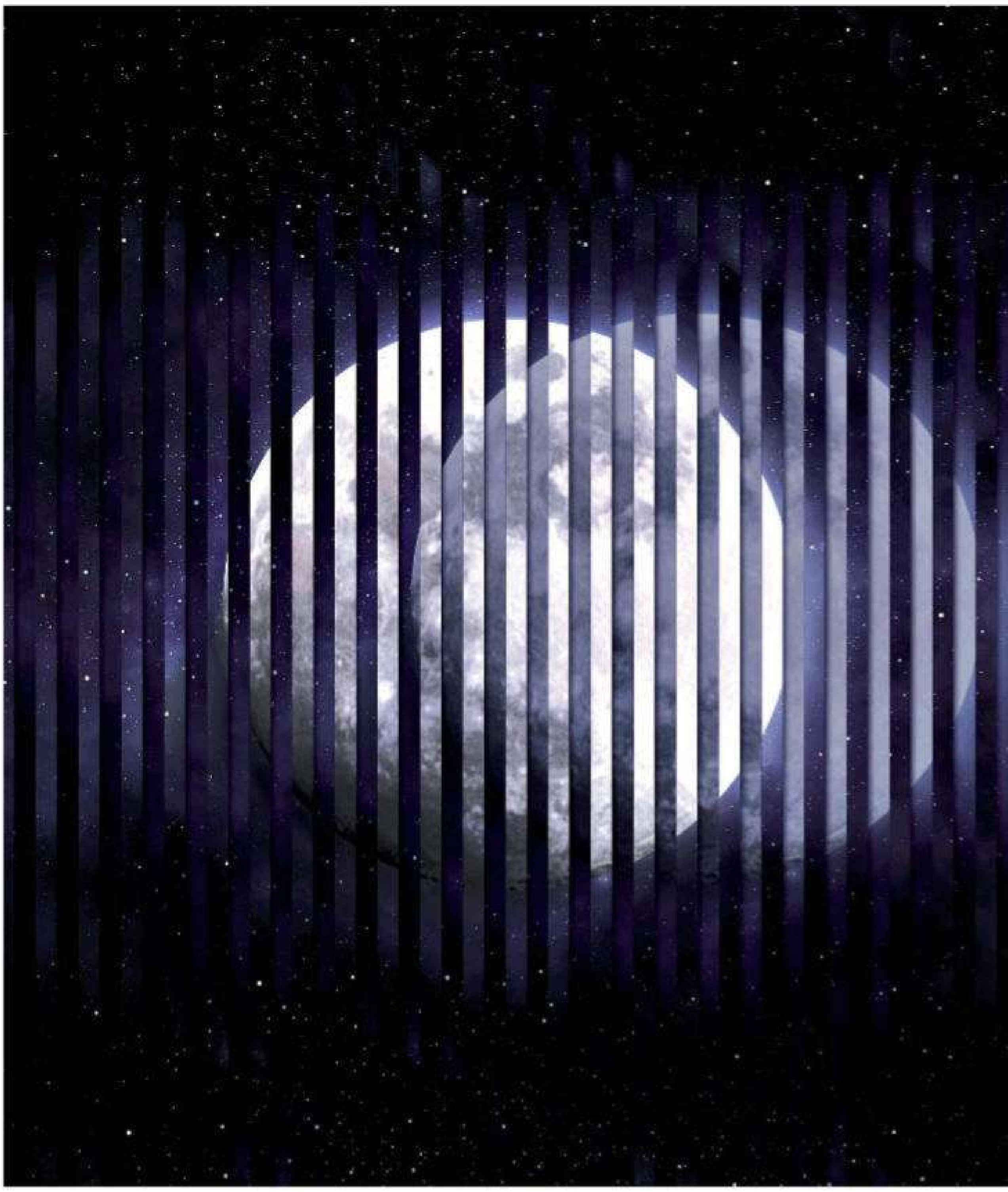
The largest things currently known to behave in a quantum way were observed by Markus Arndt and his colleagues at the University of Vienna, Austria, who were performing a different kind of experiment. In 2020, they used a double-slit set-up, passing objects

›

through a slit one at a time to see if they behave like waves by forming interference patterns, to show that proteins obey quantum rules.

This approach has its problems. When you are working with big, complex objects, their quantumness quickly disappears as a result of interaction with the surrounding environment – a phenomenon called decoherence. Quantum states are fragile. They easily break under bombardment from gas molecules, stray photons of light and even delicate electric and magnetic fields. "Any quantum object can behave classically if you're not treating it properly," says Chiara Marletto at the University of Oxford. This is especially troublesome for double-slit experiments because it takes a long time to build up the double-slit interference pattern – time in which decoherence can run riot.

Leggett-Garg experiments are just as tricky. They have their own sources of decoherence, but researchers must also find ways to measure a system without disturbing it. Only by doing this can you say for sure whether the object is in a quantum superposition or not. "You have to do the measurement in a clever way," says Sinha. "You're trying to measure something, but on the other hand, you want to ensure that the act of measurement doesn't leave any invasive mark."



It is impossible to drag most quantum systems – which move in discrete steps – into the classical world, where movement is continuous. This makes it hard to examine quantum objects and the stuff we would usually think of as classical in the same experiment. But Sougato Bose, a theorist at University College London, has a plan. He proposes using an experimental set-up that can transcend the classical and quantum worlds.

The set-up he has in mind, a simple harmonic oscillator, comprises an object trapped inside a well, moving back and forth like a swinging pendulum. Precisely how it oscillates depends on whether it obeys quantum or classical rules. And as there is theoretically no limit to how big a simple harmonic oscillator can be, Bose and his collaborators hope to use it to take a leap into the macroscopic world – using a nanocrystal 100,000 times more massive than objects tested by Arndt's team.

To do this, the researchers' idea is to look for the swinging nanocrystal when they expect it to be exactly in the middle of the oscillator, on the border between left and right (see "Reality in the balance," right). "We don't observe, and then we suddenly take a snapshot observation," says Bose. But crucially, the detector will only be able to see one half of the oscillator. If it sees the nanocrystal, the researchers know it is in that side. If the detector doesn't, they know it is in the other.

If the crystal is behaving in a classical way, it should be there half of the time on this first measurement. Then, after waiting the time it takes to complete half a swing and so return to the centre of the system, the researchers would measure again and would expect to see it half the time. But if the particle is quantum, the act of not seeing it in one half of the oscillator would collapse its so-called wave function – the mathematical description of the quantum state. Even though we don't see the nanocrystal, we now know its position, and because of quantum uncertainty, this injects the particle with momentum and changes the way it is oscillating. By repeating measurements at set intervals, the researchers hope to be able to build up correlations that tell them whether the nanocrystal is behaving in a quantum way or classically. The trick in all of this is to throw out the measurements in which the nanocrystal is seen and only keep the ones in which it isn't, so that the measurements are non-invasive.

Since Bose and his collaborators proposed the experiment in 2018, advances in the trapping and cooling of nanocrystals to avoid decoherence, alongside new precision lasers, mean the idea can now be realised. Teaming up with Hendrik Ulbricht, an experimentalist at the University of Southampton, UK, Bose plans to carry out the test on a nanocrystal made of about a billion atoms. "It's a big jump," says Ulbricht.

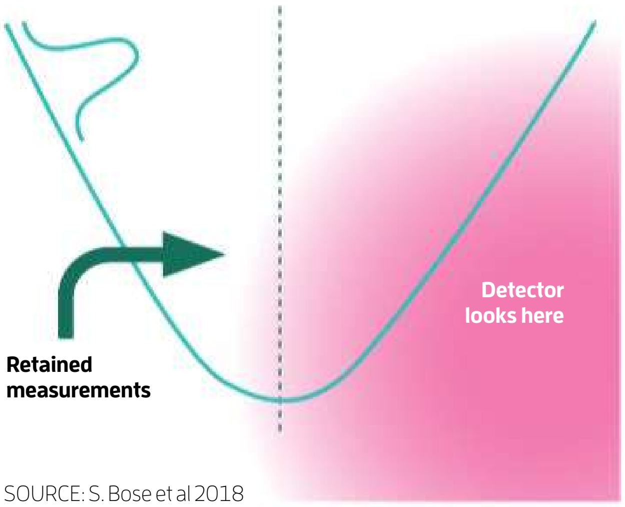
Only recently have lasers become sharp enough to determine which side of the trap the nanocrystal is oscillating in. Bigger particles are described by smaller waves and so for these

“A brick wall between the quantum and classical worlds would save reality as we know it”

DENBAGOESKHOLLI / SHUTTERSTOCK

Reality in the balance

In a proposed experiment, a macroscopic object is placed in a harmonic oscillator while a detector looks at one side at set intervals. By only retaining measurements where the object isn’t seen, you can determine whether not seeing it changes how it is oscillating – if it does, you know you are dealing with a quantum system



SOURCE: S. Bose et al 2018

nanocrystals, the laser must be able to resolve widths about the size of a water molecule. Ulbricht and Bose expect to have results within the next six months. If the experiment violates Leggett-Garg inequalities, it will break the concept of realism in macroscopic objects.

Still, even if this is the end result, it will be hard to convince everyone that the quantum world extends this far. For one, Leggett-Garg experiments actually test whether a system behaves classically; if it doesn’t, it is assumed to be behaving quantum-mechanically, but that might not truly be the case. Another stumbling block is the array of loopholes that might lead to Leggett-Garg inequalities being violated even though the system is behaving classically. Although measurements should be non-invasive, the practicalities open up so-called clumsiness loopholes. “The stubborn macrorealist cynic could always say: ‘Ah, the measurement itself disturbed the system’,” says Halliwell, who is dreaming up new methods of measurement to avoid such problems.

Brick walls

Then there is the collusion loophole, in which particles outside your experiment make it look like macrorealism is violated when it isn’t. And let’s not forget the detection loophole, where a detector’s inability to register every particle that comes its way can distort the result.

Researchers like Sinha are busy trying to close all the possible loopholes in Leggett-Garg experiments. Earlier this year, her lab carried out the most watertight test of macrorealism yet, according to Halliwell, in a system made of photons. “We have closed the remaining loopholes for now, but you can never claim that it’s completely loophole-free,” says Sinha.

Loophole-free tests of Bell’s inequality were only published in 2015, half a century after Bell’s original idea. Even now, eagle-eyed physicists keep pointing out possible new cracks in the design of these experiments. Ulbricht acknowledges that their experiment is likely to contain loopholes too. “There will be a very healthy and long debate, I’m sure,” he says.

No experiment has ever contradicted quantum mechanics. And there is no reason to think that quantum weirdness doesn’t apply to objects as big as the moon and beyond, so long as you isolate your system from the environment’s decoherence. “From a theoretical point of view, quantum theory doesn’t put any limitation on how large an object you can put in a quantum superposition,” says Marletto.

But Ulbricht hopes that these experiments might reveal a brick wall that no quantum system can go beyond. Such a wall between the quantum and classical worlds would save reality as we know it, offering a way for our common-sense world to appear out of quantum weirdness. “There could be a universal mechanism, which is turning all quantum systems into classical ones as soon as they hit the brick wall,” he says. One idea, suggested in 1987 by Lajos Diósi at the Wigner Research Centre for Physics in Hungary and Roger Penrose at the University of Oxford, is that our classical reality emerges through instabilities in the structure of space-time.

By testing whether quantum mechanics applies to bigger and bigger objects, Ulbricht says we can rule out some models of objective collapse theory, an extension of quantum mechanics that makes predictions about where the brick wall should be. Yet it will be impossible to be certain this wall exists, as the collapse might be caused by run-of-the-mill decoherence. “Sometimes, the environment may be very conspiratorial,” says Bose. Whether a brick wall or something else entirely, “finding a deviation from the predictions of quantum theory – whether or not you like quantum theory – is great, because we would be able to then try to find a new theory”, says Marletto. “People are frustrated that quantum theory is really good at being confirmed experimentally.”

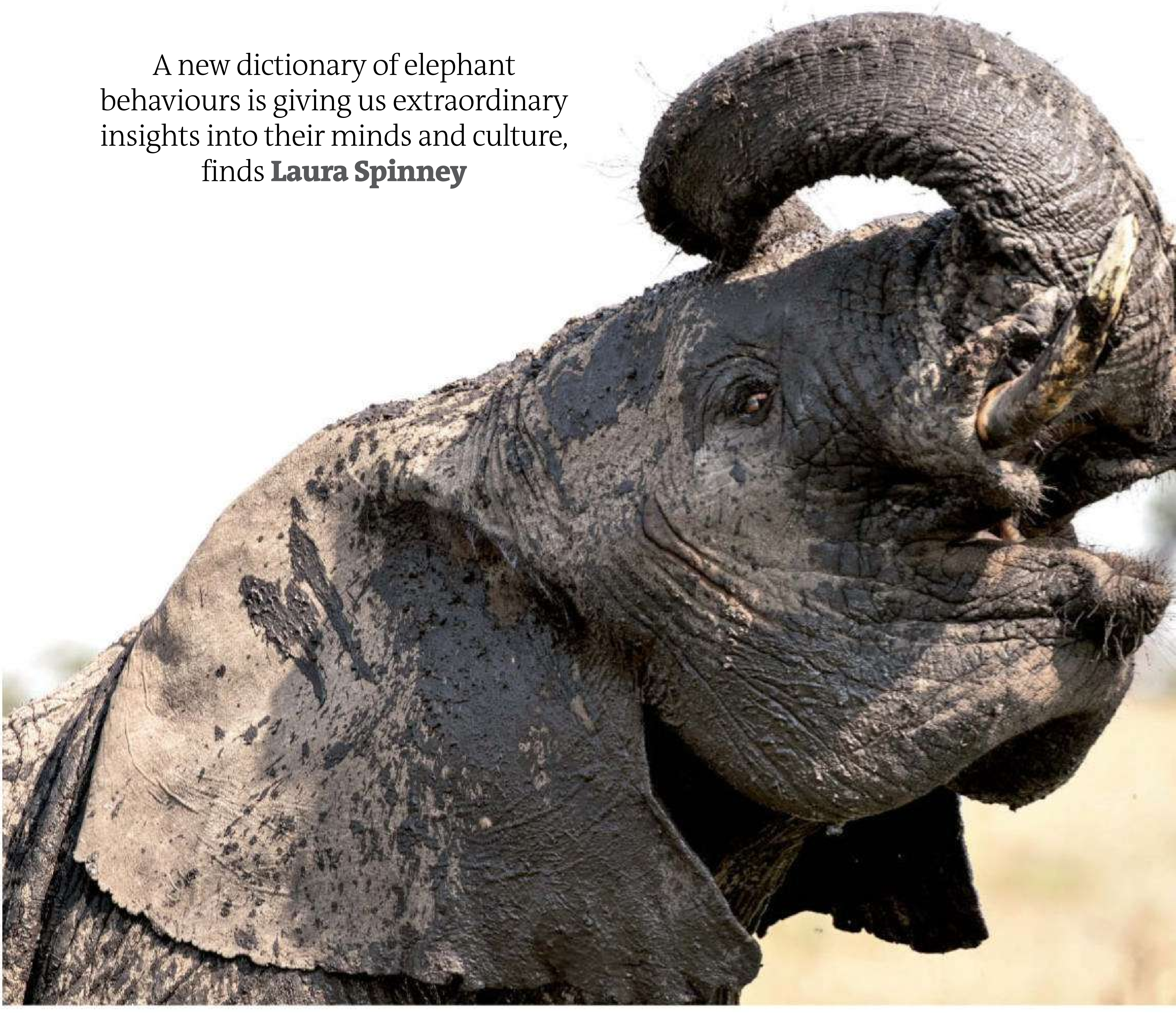
So is the moon there when you don’t look, or is that tree in the forest even there to fall in the first place? As tests of Leggett-Garg inequalities creep into the truly macroscopic world, the answer, increasingly, is no. “If macroscopic realism is violated, then you can’t assume the moon is there,” says Halliwell. Reality as we think of it might not be real after all.

It is even possible that future Leggett-Garg inequalities would not only disagree with the rules of the classical world, but also break the so-far unbreakable quantum ones. “This would give you a glimpse into some kind of post-quantum world,” says Vedral. “It’s hard to imagine what this could be, but I think we’re going to find something even weirder.” ■

Thomas Lewton is a freelance writer based in London

Deciphering Dumbo

A new dictionary of elephant behaviours is giving us extraordinary insights into their minds and culture, finds **Laura Spinney**



ELEPHANT VOICES

A young male tosses his head, advertising that he is in musth, a period of increased sex drive

A HERD of around 40 elephants processes across open grassland in Mozambique's Gorongosa National Park. Led by a matriarch named Valente, they are headed towards a newly felled tree, a potential food source. The tree is out of sight: perhaps the elephants detected vibrations from the impact through their feet. That's cool, and the procession is impressive – but elephant scientist Joyce Poole isn't sure why this particular video went viral. Since May, she and her husband Petter Granli have been posting clips of elephants daily on social media, and others are far cuter or odder.

The duo are co-founders of a US-based non-profit organisation called ElephantVoices, and these videos are part of a project they have been working on for the past five years. Called the Elephant Ethogram, it is a freely available online library of elephant behaviours and vocalisations, along with their meanings. Since it went live, Poole and Granli have been inundated with messages expressing wonder and gratitude.

This shouldn't come as a surprise. The human desire to decipher other animals is ancient, and science has recently brought that dream closer – through, for example, the use of artificial intelligence to start decoding the vocalisations of whales and birds. The Elephant Ethogram is less flashy, but far more impressive. Andrew Whiten, who studies animal behaviour at the University of St Andrews, UK, calls it a "staggering achievement". It is probably the most ambitious ethogram ever created. As well as giving anyone the pleasure of understanding elephants more intimately, it could transform the way researchers see these magnificent animals – and even help avert their extinction.

You can think of an ethogram as a foreign-language dictionary for an entire species that covers actions as well as sounds. The concept dates back to the mid-20th century, when pioneering ethologists like Nikolaas Tinbergen and Konrad Lorenz drew up the first ones for species whose behaviour they thought of as innate and stereotypical – mainly insects, birds and fish. Several now exist for the mouse, that staple of laboratory research. But intelligent, socially complex animals represent a much greater challenge, and you can count the number of ethograms that cover them on the fingers of one hand. For cetaceans, there is a book called *The Cultural Lives of Whales and Dolphins*. For chimpanzees, says Whiten, the most comprehensive one is probably another book called *Chimpanzee Behavior in the Wild*. And now there is the Elephant Ethogram.

This new lexicon is in a different league. It is the first online database for a big-brained animal – a format that lends itself easily to updating, which is useful if you are interested in behavioural change – and it is searchable. It contains 425 behaviours, illustrated with some 3000 annotated video clips, audio recordings and photographs, and draws on scientific papers dating back more than a century. Despite its unprecedented detail and scope, it is very much a work in progress. Poole and Granli hope that other scientists will contribute to it as time goes on. For now, though, it only covers African savannah elephants from Gorongosa and two other sites – Kenya's Maasai Mara ecosystem and Amboseli National Park.

Human-like behaviour

Already, to plunge into the ethogram is to discover the astonishing range and flexibility of elephant behaviour. You soon realise that context matters, with the same behaviour meaning different things in different settings. Take tail swatting. When forcefully applied, it often means "keep your distance", whereas from a mother to her calf, it says: "Are you there baby?" It can even signal appeasement, says Poole, pointing to the example of Qaskasi, a young female in Amboseli. Adolescent female elephants play an important role in helping to care for the young of older females, but their efforts aren't always welcome. Videos show the matriarch Qoral repeatedly pushing Qaskasi away from her newborn. Then, after the hapless Qaskasi has fallen on the calf, she tries to make amends by gently tail swatting a ruffled Qoral.

You may think this story has echoes of human behaviour, and it isn't the only one. In another clip, a male named Icarus approaches his human observers with a swagger. This behaviour, called a musth-walk, is typical of males in musth, when they have a heightened sex drive. Like Icarus, they are essentially strutting their stuff in front of potential mates. Those aren't Poole's words, but she isn't

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“This information could prove invaluable for rewilding efforts”

afraid of anthropomorphising. “To me, it’s not a dirty word,” she says. “Elephants are mammals like us – it’s not surprising that we have certain behaviours in common.” It is now accepted, for instance, that they can grieve over the loss of a relative, and express joy on the birth of a calf. Comparison with human behaviour can be useful for conveying succinctly what the elephants are doing, too, as in the case of “high-fiving”, a greeting (though it is more besides) that involves them raising and intertwining their trunks.

If Poole feels confident that she understands most of the behaviours in the ethogram, more or less, it is because she and others have seen them crop up repeatedly in similar situations – the fruit of long hours of observation in the field (see “Watching you, watching me”, below). “The attention to detail in Joyce and Petter’s work is amazing,” says Lucy Bates at the University of Sussex, UK, who studies elephant cognition. “The tiniest, subtlest movements that are so easy to miss have been highlighted and described, which could save huge amounts of time and effort for people just learning about elephant behaviour.” For her, however, the most exciting prospect is that researchers will be able to take a given behaviour in the ethogram and look for it in the population they study. “It can generate a lot more data to help us understand why elephants do certain things,” she says. “Periscope-trunk”, for example, was once thought to be a form of sniffing, but is now considered both that and a signal with multiple meanings. In a procession, it might serve to point towards the collective destination, while an infant doing it in its mother’s presence is probably asking to suckle. In sparring males, it means: “I’m ready, what’s your next move?”

There are a few behaviours in the database that Poole admits still puzzle her. One is “stand-over-bush”, where young females straddle a certain kind of shrub, the croton bush, and “go all doe-eyed”, as Poole puts it. She wonders if they are rehearsing for motherhood: “That was my thought when I saw it, but I don’t know,” she says.

Stand-over-bush has only been observed in the Maasai Mara elephants so far, so it could be an example of a behaviour that emerged and spread in one population and not in others. There is strong evidence for such distinct cultural practices in cetaceans and apes – for example, in the songs of whales and the use of tools by chimps – but evidence of culture in elephants is sketchier. “We still don’t really know if all behaviour is universal in [savannah] elephants or if there are differences in who does what, where, when and why,” says Bates.

A cultured animal

The case for elephant culture is building, though. At Tsavo East National Park in Kenya, semi-captive elephants have been recorded mimicking the sounds of lorries on the nearby Nairobi-Mombasa highway. At Gorongosa, where 90 per cent of elephants were slaughtered when civil war raged in Mozambique between 1977 and 1992, the remaining elephants learned to be aggressive – and remain so today. “They’ve passed it on to their offspring now,” says Poole. “Furthermore, each family has its own traditions for attacking.” Some charge as a group, while in others only the matriarch sallies forth. Not for nothing did two Gorongosa females earn the

Watching you, watching me

One of the sacred tenets of the study of animals is to try to influence the behaviour under observation as little as possible. This becomes difficult when a behaviour is itself an adaptation to humans. Joyce Poole, co-founder of ElephantVoices, has found herself in the surreal situation of listening in as elephants discuss what to do about the humans in the vicinity. “We may be monitoring them with drones, planes and satellite collars, but they’re monitoring us 24/7 too,” she says.

Poole has seen elephants gather at the boundary of a conservancy of an evening, in preparation for a raid or to reach a habitat beyond neighbouring human settlements. Family members deploy the “let’s-go rumble”, but the matriarch, listening to the receding human voices and cattle bells, refuses to be rushed. “They’re saying, ‘Let’s go, let’s go, let’s go’, but she’s waiting, listening and sniffing,” says Poole. “Then she decides it’s safe to go, and they move in a tight bunch – I call it a ‘group march’ – leaving the conservancy because they know that people are going to bed, it’s getting dark and they can head outside.”

Elephants are intelligent enough to make that kind of call, in other words. But they may not be intelligent enough to predict the potentially dire consequences for themselves of a clash with humans. And there’s the rub. Their best hope of survival might be for us to use our understanding of elephants to teach them how to resist us better. Poole is working on that by decoding what elephant behaviours and vocalisations mean (see main story).

ELEPHANT VOICES

ELEPHANT VOICES

In Gorongosa National Park in Mozambique, matriarch iJunia shakes her head, signifying annoyance (above), and four young males (left) adopt a "periscope-trunk" posture to sniff out a film crew

names Provocadora and Ambuscadora. The elephants that live in Amboseli, which are used to tourists, are far less aggressive.

"Capturing behaviour in an ethogram helps us spot cultural diversity," says Whiten. The burgeoning realisation that behavioural and cultural diversity is widespread in the animal kingdom doesn't seem to sit well with the original idea of an ethogram as an exhaustive and definitive lexicon of innate and stereotypical behaviours. Yet they can be invaluable for that very reason, he says. "We tend to think of culture as varying over space, but it varies over time too." An ethogram can capture both dimensions.

As researchers begin to map out a species' cultural range, they can also probe the frontier between normal diversity and abnormal behaviour or sickness. For example, Poole describes the behaviour of a young male she observed manipulating a twig between his armpit and his nipple as "idiosyncratic". But the repeated tugging on the nipple that has been reported in some captive elephants is aberrant because, along with other repetitive, apparently pointless actions, it is only seen in captivity, she says. Knowing what is abnormal obviously has welfare implications. Captive elephants often lack space in which to forage and other elephants to interact with, and their behaviour is impoverished as a result. Most zoos and circuses are now at least aware of the need to enrich animals' environments – that is, provide them with psychological and physical stimulation comparable to what they would receive in the wild. Understanding the subtleties of their behaviour can help with this.

Such knowledge is also crucial for captive breeding programmes. There have been successful attempts to teach captive-born animals the skills they need to survive in the wild before they are returned there. For example, golden lion tamarins experienced high casualties when they were first released in the early 1980s after a captive breeding programme brought them back from the brink of extinction. But they did better after they were given temporary post-release support to help them acquire survival skills – which they later passed on to their wild-born offspring. Now that plans are afoot to rewild some captive elephants for the first time, Poole hopes the same approach can be applied to them.

But influencing the behaviour of an intelligent, cultured animal can be challenging. Philippa Brakes, at UK-based charity Whale and Dolphin Conservation, points to an anecdotal report of an orca that had been raised in the wild eating mammals, including seals and dolphins, and starved to death in captivity rather than switch to fish. Yet orcas must change their behaviour sometimes because populations around the world have some unique foraging traditions, she says. Once an individual has innovated, there is probably a host of factors that determine whether others follow suit to create a new culture. These factors may vary for different animal species, too. "We don't yet understand enough about how these behaviours are transmitted in the wild," says Brakes.

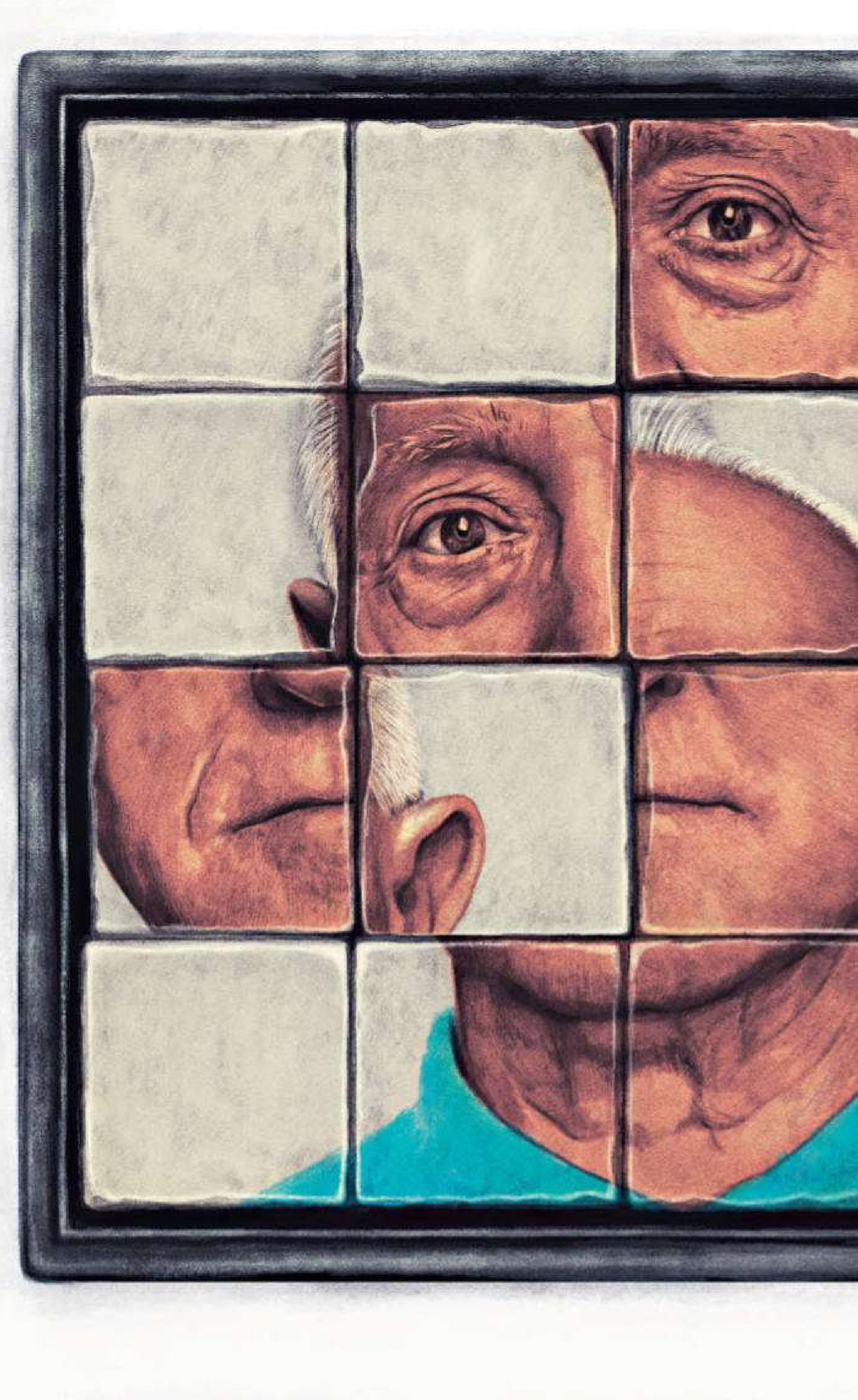
As the Elephant Ethogram expands, the information it contains could prove invaluable for rewilding efforts. Indeed, conservation could be the driving force behind a new vogue for ethograms in general. Knowing that older female elephants are the repositories of learning in a family, or that whales transmit information about foraging grounds across generations, is essential to understanding where a depleted population's vulnerabilities lie – and hence how to protect it. But to actually apply such knowledge, you have to understand how cultural practices vary across a species. That's why, since 2014, the United Nations has backed a movement to integrate research on animal culture into conservation policy and practice. Brakes, who chairs a UN expert group on animal culture, says she looks forward to the day when ethograms exist for all the vertebrate groups that we know learn socially, everything from birds to whales to lizards. "We need to adjust the way we draw lines around populations, factoring in not just geographic distribution and genetic diversity, but also culture," she says.

The urgent need to do this for elephants – which are endangered the world over – is what prompted Poole and Granli to devote years to building the Elephant Ethogram. But they also want to raise public awareness of the plight faced by these majestic and intriguing animals, they say. "We hope it will remind people what will be lost if we don't change course." ▮

Laura Spinney is a science journalist based in Paris and author of *Pale Rider: The Spanish flu of 1918 and how it changed the world*

Piecing it together

A new approach to Alzheimer's disease is changing how we search for its cause, and could finally give us effective treatments, finds **Hannah Thomasy**



FOR the first time in nearly two decades, a new treatment for Alzheimer's disease was approved by the US Food and Drug Administration in June. But instead of joy and relief, the announcement was largely met with frustration and even anger. Some experts pointed out that the clinical trial that was the basis of approval for Biogen's drug aducanumab didn't conclusively show that it reduced cognitive decline. Instead, the FDA based its unprecedented decision on evidence that the drug treats the underlying cause of Alzheimer's.

The trouble is, it is far from clear that the target of this drug – clumps of beta-amyloid protein – is truly the cause. Drugs aimed at beta-amyloid have failed time and time again. Large-scale clinical trials representing billions of dollars of research have shown no positive impact; some experimental medicines even seemed to make cognition worse.

With this new drug, there were also concerns about the FDA approval process. Ultimately, the agency's acting commissioner Janet Woodcock requested an investigation into her own agency's decision-making.

But the controversy isn't limited to this decision. The big worry is that the continued focus on beta-amyloid is a dangerous distraction, that it may actually obscure the complex nature of the disease and waste precious time. The growing consensus is that there is no single cause of Alzheimer's, but a complex web of contributing factors. That may not seem like good news, but there is a silver lining: many different factors can provide many paths for treatment.

The only way is amyloid

Worldwide, there are 10 million new cases of dementia every year – and roughly two-thirds of these are Alzheimer's disease. Staggering sums of money have been invested to try to understand the underlying cause, with much of the focus on one explanation.

Initially, there was good reason for that. The amyloid hypothesis gained popularity

PETER STRAIN

in the 1990s after the discovery of three rare genetic mutations involved in the formation of beta-amyloid. Having one of these essentially guarantees that a person gets early-onset Alzheimer's – when the disease occurs before the age of 65. Since beta-amyloid plaques in the brain are a hallmark of the disease, it seemed likely this was the culprit. Other contributing factors were acknowledged, but the idea was that these followed the initial problem with amyloid, in what is known as the "amyloid cascade" hypothesis.

So far, amyloid-busting drugs have failed to actually improve symptoms of the disease. But some experts hope they might yet be effective, if they are given before symptoms appear – and other candidates are now in late-stage trials.

Rudolph Tanzi, who studies the molecular genetics of Alzheimer's at Harvard University, says the thinking now is that the role of amyloid in Alzheimer's is similar to the role of cholesterol in heart disease, in that levels are elevated for decades before the onset of symptoms. If doctors can spot high cholesterol levels early, they can prescribe medications to lower them and prevent heart damage. But once a person has severe congestive heart failure, these drugs will be insufficient. It isn't routine for doctors to measure beta-amyloid levels in people, so by the time someone has symptoms of Alzheimer's, clearing up plaques won't undo the damage. Many people are searching for biomarkers to help us detect the disease years before symptoms appear, and so give these preventive treatments a fighting chance.

Tangled up in tau

Beyond beta-amyloid, another major hallmark of Alzheimer's in the brain is accumulation of a protein called tau. In healthy brains, tau helps to support the structure of neurons, but certain changes can cause it to clump together inside axons (the arms connecting the main body of a neuron to other cells), interfering with a neuron's ability to communicate.

Once people develop Alzheimer's, the amount of tau build-up actually correlates better with dementia severity than the amount of beta-amyloid, which suggests it plays an important role in the progression of the disease once symptoms have begun, says Einar Sigurdsson at New York University. "Targeting tau is probably a more feasible approach in the later stages of the disease," he says.

Unfortunately, here too, we don't yet have any successful drugs. As the vast majority of tau build-up is inside neurons, targeting it is tricky. Tau can also take many different forms, and it is unclear which are the best to target. A few trials of tau-targeting antibodies have failed, but other therapies are in development.

In the meantime, there are things we can do to reduce our risk of accumulating harmful tau tangles. Sigurdsson says there has been relatively little research on how lifestyle factors affect tau pathology, but that in general "what's good for your heart is good for your brain".

Clues in our genes

Genes clearly play a part in Alzheimer's disease, because a small proportion of cases occur earlier in life, as a result of specific genetic mutations. These are exceedingly rare – about 5 to 6 per cent of Alzheimer's cases are early onset and only a fraction of these are caused by the mutations. But there are many more common gene mutations loosely connected with late-onset Alzheimer's disease. The gene with variants most commonly associated with late-onset disease is called *apolipoprotein E* (*APOE*): the *APOE e2* variant reduces risk and the *APOE e4* variant increases it.

Researchers are studying the roles of *APOE*. The *e4* variant seems to promote formation of beta-amyloid plaques and may also increase neuroinflammation that affects the function of the blood-brain barrier, the protective layer that controls the movement of molecules and cells between the brain and the bloodstream.

While some strategies targeting *APOE* seem promising in animals with Alzheimer's-like illness, very few have been tested on humans. One especially interesting early stage trial is now testing whether a therapy that delivers the protective *APOE e2* gene has any beneficial effects for people who carry two copies of the harmful *APOE e4* variant.

Unfortunately, for now, there is nothing you can do about your genes, and genetic testing for *APOE* variants isn't generally advised. That is because it doesn't definitively determine whether you will get the disease – plenty of people with the protective form still get Alzheimer's and plenty with the risk-enhancing form never do.

Outside invaders

Infections may also play a role in the likelihood of someone developing Alzheimer's. Although there have been conflicting findings over the years, evidence is building that certain viruses and bacteria increase risk.

In particular, research has implicated

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bacteria that cause gum disease. A study of nearly 30,000 people suggested that having severe gum disease for at least 10 years increased the risk of developing Alzheimer's by about 70 per cent. In 2019, researchers at US biopharmaceutical company Cortexyme published findings on a specific gum disease bacterium called *Porphyromonas gingivalis*. They found this microbe – as well as the toxic enzymes it produces – in the brains of people with Alzheimer's after they had died. In mice, they showed that this bacterium could migrate from the mouth to the brain. Giving the mice a drug that blocks the activity of the toxic enzymes reduced inflammation in the brain and lowered levels of one type of beta-amyloid. The company has now recruited more than 600 people with mild to moderate Alzheimer's disease for a clinical trial of the drug. Results are expected by the end of 2021.

As for how to reduce your risk: there isn't yet a direct link between dental hygiene and Alzheimer's risk, but it is probably a good idea to brush, floss and see your dentist regularly.

Friendly fire?

It may not be the microbes themselves causing Alzheimer's, but rather how our bodies respond to them and other perceived threats. Multiple studies have indicated that infection with herpes viruses can trigger beta-amyloid accumulation, for example. Initially at least, this response may protect the brain: Tanzi, along with colleagues Robert Moir and Richard Lathe, has hypothesised that amyloid is actually an antimicrobial protein that sticks to and neutralises viruses or bacteria that get into the brain. At first, amyloid triggers an immune response – inflammation – which helps to clear the infection. But if inflammation persists, it can cause harm. One aspect of this inflammatory response is that brain cells known as microglia and astrocytes become activated into a neuron-damaging state, "housekeepers turned killers", says Tanzi.

He and others are trying to find a way to flip the switch back. "We've been screening every approved drug, every natural product, for the ability to tell microglial cells and astrocytes to stop killing and go back to work as nurturers and housekeepers for the neurons," he says. So far, they have about 35 promising substances. The next step is to test these in animals.

But taming microglia is just one way to reduce inflammation, which can be triggered in many ways. We know, for instance, that people with autoimmune disorders such as rheumatoid arthritis or Crohn's disease have higher levels of a pro-inflammatory protein called tumour necrosis factor (TNF). Malú Tansey, director of the Center for Translational Research in Neurodegenerative Disease at the University of Florida, says that people with long-term elevated levels of TNF have a higher risk of developing neurodegenerative disease, but that anti-TNF therapies can reduce this. In mouse models of Alzheimer's, Tansey and her colleagues have shown that blocking TNF helps improve neuronal function.

Tansey says build-up of proteins like beta-amyloid is important for Alzheimer's, but doesn't believe it is the initiating factor. "We need to think about protein aggregation not as triggering the inflammatory immune dysfunction, but resulting from it," she says. By identifying and treating immune dysfunction, we may be able to prevent the disease.

Covid-19 and cognition

Several studies have confirmed that there is a risk of covid-19 having neurological and psychiatric complications, such as anxiety, depression and delirium. More recently, we have begun to uncover worrying connections between coronavirus infection and Alzheimer's-like symptoms in some people. Gabriel de Erausquin at the University of Texas Health Science Center at San Antonio is conducting a study on older people who tested positive for the virus. "What we found is that a remarkable number of people over 60 years of age that have been exposed to the virus – compared with people who remained PCR-negative – have cognitive impairment. It's close to 60 per cent," he says.

De Erausquin says this is about 10 times more than he would have expected in a group of this age. He says that while many people primarily had forgetfulness, others had more severe impairment, including problems with attention and language. While some of the people in this study ended up in hospital with covid-19, most didn't, and initial severity of symptoms wasn't related to the severity of later problems with cognition.

Other research presented at the recent Alzheimer's Association International Conference in Colorado analysed blood biomarkers in people with covid-19 who ended up in hospital, with and without neurological symptoms. Those with certain neurological symptoms had elevated levels of biomarkers related to Alzheimer's disease and neuronal damage, including tau and a protein called neurofilament light chain.

While it is possible that the changes de Erausquin and others have observed are the beginnings of Alzheimer's, it is also possible that these individuals will recover. We simply don't have enough information yet. Right now, says de Erausquin, "the crucial experiment is to figure out what is the course of this".

“Alzheimer’s, as currently understood, is really not a single disease”

But what kicks off inflammation and TNF production in the first place? While genes are one factor, Tansey’s research also suggests that diets high in fat and sugar can lead to inflammation and immune dysregulation, including in the brain. Blocking TNF can prevent many of these effects, she says.

It remains to be seen if these findings can be translated into treatments. Until then, there may be other ways to reduce inflammation. While there are some exceptions, research generally shows that exercise and diets low in red meat, saturated fat and sugar support healthy brain function as we age.

Off to sleep

Again and again, studies have linked Alzheimer’s disease and sleep problems, but the nature of this relationship isn’t fully understood – and probably goes both ways. While we sleep, potentially harmful proteins are flushed away by the brain’s waste-removal apparatus, the glymphatic system. Even a single night without sleep can increase levels of beta-amyloid in our brains. But lack of sleep can also promote tau accumulation and inflammation in the brain. Additionally, the mechanisms controlling our body clock may play a role in the development of neurodegenerative disease, says Erik Musiek at Washington University in St Louis, Missouri, by regulating sleep patterns and inflammation.

Drugs currently used to treat sleep disorders such as insomnia could be useful against Alzheimer’s as well, says Musiek. Mouse studies have shown that a type of drug known as an orexin antagonist reduces beta-amyloid levels in the brain. A clinical trial in humans is expected to start this month.

Musiek says that working out how sleep and our body clock protect our brains is important for finding new treatments. “If we knew that when we sleep it activates this particular pathway in this particular kind of cell, and that’s why [sleep] is protective, then you could just make a drug that does that.”

In the meantime, there is plenty we can do to improve the quality of our sleep, which, unlike prescription drugs, has no negative side effects. The American Academy of Sleep Medicine recommends getting at least 7 hours per night and adopting good habits such as maintaining a consistent sleep schedule and avoiding bright light and caffeine in the evenings.

A blow to the head

We now know that brain injury can increase the risk of developing dementia later in life: one study of more than 350,000 people found that even mild head injuries more than double the risk of dementia. While Alzheimer’s is the most common form of dementia, there isn’t conclusive evidence that head injury leads to it specifically, says Kristen Dams-O’Connor, a neuropsychologist and specialist in brain injury at Mount Sinai Hospital in New York. There is overlap between Alzheimer’s symptoms and those experienced after traumatic brain injury “which can make it difficult to disentangle them”, she says.

It is important to stress that brain injuries are just one of many risk factors, and even if people who have had a traumatic brain injury (TBI) are, on average, at a greater risk

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Reserve and resilience

While many scientists study factors that increase our risk of developing Alzheimer’s disease, others are interested in factors that promote resilience to it. One way to study this is by looking at families with rare genetic mutations that almost always lead to early-onset Alzheimer’s. Occasionally, someone will inherit this mutation but won’t go on to develop the disease.

In one case, a woman had another rare genetic mutation called the Christchurch mutation in the *APOE* gene, which appeared to be protective. *APOE* plays a role in Alzheimer’s (see main story) and studying its harmful and protective functions may lead to therapies.

Another research group has identified resilient individuals who don’t carry the Christchurch mutation, hinting that other genetic protective factors may be at play too.

We can’t change our genes (at least not yet). However, several studies have suggested that people with higher cognitive reserve are more resilient to cognitive decline related to Alzheimer’s disease, meaning they maintain normal functioning despite build-up of plaques in their brains.

Cognitive reserve appears to be at least partially under our control, factors like higher education and bilingualism and even whether you have a stimulating job seem to promote resilience to dementia symptoms.

for neurodegenerative disease, "most TBI survivors will not develop dementia", says Dams-O'Connor. "Studying those [who don't] is just as important as studying those who decline, as it can begin to point us toward resilience factors – some of which may lead to additional treatment targets."

Effective treatments for long-term brain injury symptoms are limited, but Dams-O'Connor says we can help safeguard brain health after a head injury with healthy diet, good sleeping practices, exercising, keeping socially active and pursuing cognitively demanding activities. She also stresses the importance of regular medical visits.

Preventing head trauma in the first place is also important, especially for older adults. Using a seatbelt, wearing a helmet while on a motorbike or bicycle and getting your vision checked regularly to prevent falls can all help.

ALEXEY STIOP/SHUTTERSTOCK

Traumatic brain injury can double the risk of dementia

Pulling it together

The vast majority of researchers studying Alzheimer's now acknowledge that the disease has multiple contributing factors that involve cascades of cellular and molecular processes that we don't yet understand. "Alzheimer's disease, as it is currently understood, is really not a single disease," says neurologist Costantino Iadecola at Weill Cornell Medical College in New York. "It's a number of pathologies that all result in cognitive impairment."

George Perry at the University of Texas, San Antonio, says that the past obsession with a single cause – amyloid – hindered progress. For heart disease, we have more comprehensive treatment programmes involving medicines and surgeries, but also lifestyle factors like diet and exercise. "We haven't developed that for Alzheimer's disease – why? For the last 30 years we focused on removing amyloid because it was going to cure everything," he says.

Turning to a different single cause is no better. "You would have the same problems, because it doesn't explain the full picture of what's going on. All these things fit together,"says Perry.

This new way of thinking is finally starting to change how we study the disease and share data. Initiatives such as the Global Alzheimer's Association Interactive Network, Neuronet – which was launched in 2019 by the European Union's Innovative Medicines Initiative – and the Davos Alzheimer's Collaborative launched earlier this year, aim to drive collaboration and data sharing to promote a fuller understanding of neurodegenerative disease. Given its incredible complexity, addressing Alzheimer's from multiple angles may be the only way to truly understand and treat it.

Thankfully, many researchers are striving to figure out how all these factors come together, and how each provides a different opportunity to fight the disease. Drawing on even our existing knowledge can have a powerful impact. As Iadecola says, "If you could control all the risk factors that we know of, you could reduce Alzheimer's by about 30 per cent." ▮

Hannah Thomasy is a science writer based in Toronto, Canada. Follow her @HannahThomasy

Other possible causes of Alzheimer's

BLOOD VESSELS

Until recently, it was believed that blood vessel damage seen in Alzheimer's was "secondary to the fact that the brain was dying", says Costantino Iadecola at Cornell University in New York. Now, though, there is evidence that vascular risk factors like midlife hypertension can increase the chances of developing the disease. The link between blood vessel damage and beta-amyloid build-up may go both ways too, with the plaques causing harm to blood vessels, and damaged vessels also impeding clearance of beta-amyloid.

STICKY METALS

Oxidative stress is an imbalance in the production and removal of potentially damaging reactive oxygen species, which are natural by-products of metabolism. As we age, dysfunction in mitochondria – the energy generators in our cells – can result in oxidative stress, says neurobiologist George Perry at the University of Texas, San Antonio. This in turn damages neurons and synapses – the connections between neurons essential for learning. What's more, when mitochondria aren't recycled properly, the metal ions they use, including copper and iron, can end up where they don't belong, leading to more damage. Perry says that beta-amyloid may play a role in mopping up errant ions.

Some research supports the idea that oxidative stress, mitochondrial dysfunction and metal ions play a role in the development of Alzheimer's disease, but treatments like antioxidants and chelators, which bind to metal ions, have so far largely failed to show conclusive benefits.

PRIONS

A prion is a type of misfolded protein that can cause wider damage by inducing other proteins of the same type to misfold; some argue that Alzheimer's is a prion disease.

Supporting this idea, there is evidence of forms of beta-amyloid and tau that seemed to have prion-like activity in the brains of people with Alzheimer's who have died.

If prion-like forms of these proteins are, in fact, drivers of disease, effective treatments will need to target those specific forms, rather than beta-amyloid and tau in general.

INSULIN RESISTANCE

Some studies suggest that people with type 2 diabetes are more likely to develop Alzheimer's and other forms of dementia – but the mechanisms aren't clear. Insulin seems to be important for the formation and maintenance of synapses. Insulin also affects vascular function that is crucial for supplying blood to the brain.

"DID YOU KNOW UP TO 40% OF DEMENTIA CASES COULD BE PREVENTED?"

Prof. Anne-Marie Minihane
University of East Anglia

FREE guide from experts

Many people don't know that dementia is caused by diseases. And while age and genes play a role in your risk, there are things you can do to protect your brain health and help reduce your chances of developing dementia. Get a **FREE** Your Brain Matters guide from Alzheimer's Research UK and leading scientists like Professor Anne-Marie Minihane – it's packed with information and advice to get you started.

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Alzheimer's Research UK

Alzheimer's Research UK is a registered charity, numbers 1077089 and SC042474.

Puzzles
Try our crossword, quick quiz and logic puzzle p53

***Almost* the last word**
Readers try to identify a strange marine object p54

Tom Gauld for *New Scientist*
A cartoonist's take on the world p55

Feedback
How natural disasters affect relationships: the week in weird p56

Twisteddoodles for *New Scientist*
Picturing the lighter side of life p56

Science of gardening

Banish the blight

Home-grown tomato plants can get ravaged by blight, but there are easy steps you can take to prevent it, says **Clare Wilson**

Clare Wilson is a reporter at *New Scientist* and writes about everything life-science related. Her favourite place is her allotment. @ClareWilsonMed

What you need

Tomato seeds or plug plants
A warm place to grow them

TOMATOES can be one of the easiest and most rewarding home crops. Besides thriving in the ground, they also love pots, hanging baskets and grow bags, producing loads of tasty fruits for salads, cooking and pizza sauce.

It is now the end of the tomato season in the UK and time to review the performance of this year's crop. Sadly, my plants suffered badly from blight caused by a fungus-like organism called *Phytophthora infestans*. Many other people experienced the same issue – the first signs are sinister brown spots on leaves and fruit, which spread within days to destroy whole plants.

The pathogen drifts through the air as spores and germinates best on plants in the conditions of a rainy British summer, like the one we just had. Most tomatoes grown outdoors succumb to blight by the end of the season, in autumn, but this year my plants were showing signs of infection by early August, so I got only a few fruits before the rot set in.

Once blight reaches a plant, it can't be saved, but you can take steps to reduce the chances of infection. To lessen humidity around the leaves, space out your young plants well, hold foliage up off the soil by tying it to supports and remove lower leaves as they age. Avoid splashing the leaves when you water, too.

Don't allow plants to grow from last year's fruit that fell on the ground, because they may harbour spores. (The same goes for potato plants, because this pathogen causes potato blight too.) And you can keep an eye on the "blight forecast" from blightwatch.co.uk, which tells you if the disease is on its way based on local temperature and humidity, so you can pick any ripe fruits in the nick of time.

CULTURA CREATIVE LTD/ALAMY

Most helpful of all is to choose tomato varieties that have some natural resistance to blight. I have previously been sceptical of this strategy after hearing of plants sold as blight-resistant that didn't live up to their name.

But a newer variety called Crimson Crush seems to have exceptional disease resistance. It is the first tomato to have two different resistance genes instead of one, according to the UK's Royal Horticultural Society. There are now related Crimson varieties, available from several seed suppliers.

Another good strategy is to grow several tomato varieties, if you have room, because different ones can be resistant to different versions of the pathogen, says Katherine Steele at Bangor University, UK, who helped to develop Crimson Crush. "There is a constant arms race between the pathogens and the plants."

I plan to try a few different Crimson plants next year as well as some old favourites. I would love to hear about readers' experiences with these new varieties at @clarewilsonmed on Twitter or Facebook. ▮

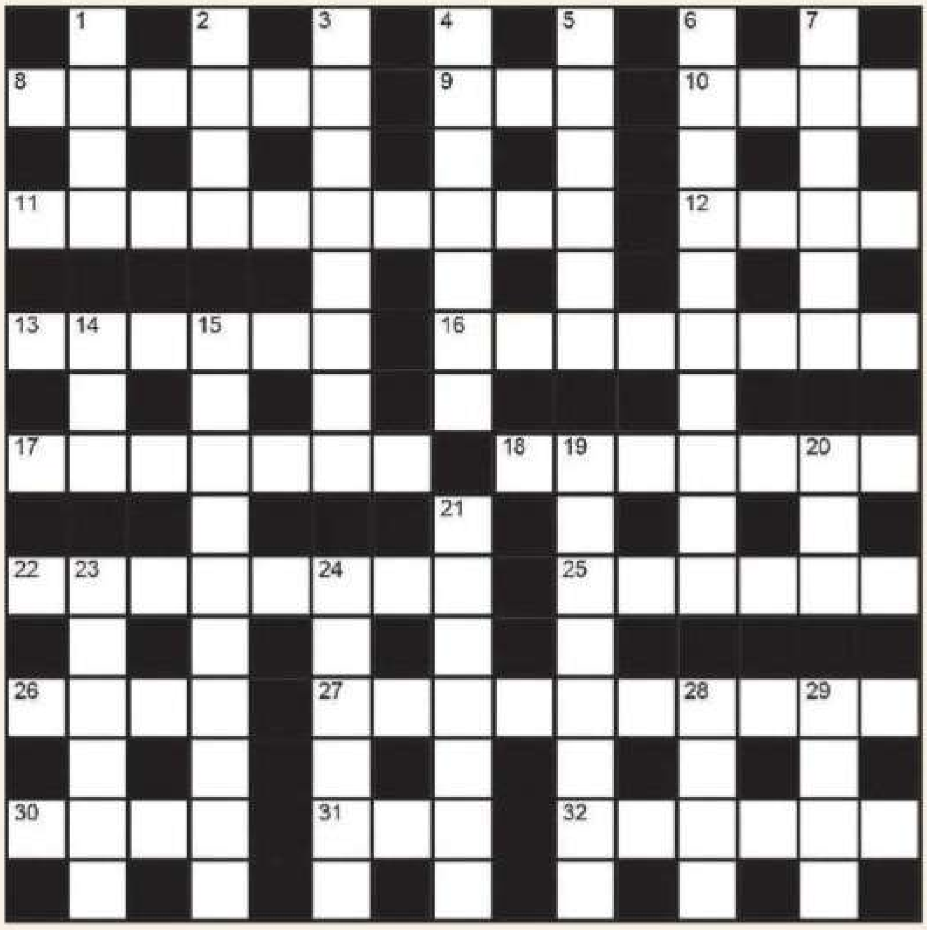
Science of gardening appears every four weeks

Next week

Citizen science

These articles are posted each week at newscientist.com/maker

Quick crossword #95 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

8 Logic-based puzzle, formerly known as Number Place (6)
9 2013 film about a man's relationship with his AI assistant (3)
10 Nutrient-bearing part of an egg (4)
11 Base 12 (10)
12 Programming language developed by Mike Cowlishaw (4)
13 Biting fly of tropical Africa (6)
16 Covert surveillance aircraft (8)
17 Digital optical discs (3-4)
18 Boris ___, Russian world chess champion 1969–72 (7)
22 Non-reproductive part of a flower (8)
25 Pa (6)
26 Unit of classification in biology (4)
27 Single-celled protozoan (10)
30 O (4)
31 File extension denoting an executable file (3)
32 Point of greatest distance between Earth and the moon (6)

DOWN

1 Neurodegenerative condition once found in Papua New Guinea (4)
2 Attraction between atoms or molecules (4)
3 Fraudulent or unproven medical practices (8)
4 Marie Curie or Dorothy Hodgkin, perhaps (7)
5 By mouth (6)
6 Reaction in which a water molecule breaks a chemical bond (10)
7 Horn or siren (6)
14 Solar day on Mars (3)
15 *The* ___, 1984 sci-fi thriller featuring Arnold Schwarzenegger (10)
19 Cervical screening (3,5)
20 Carnivorous parrot (3)
21 Less long (7)
23 Mineralised tooth surface (6)
24 John ___, British primatologist and Bigfoot researcher (6)
28 Thrombus (4)
29 Middle layer of the eye (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #126

1 Which of these is not a moon of Jupiter: Dia, Thebe or Nix?

2 If a crustacean species is carcinised, what does that mean?

3 Hans Berger is best known for inventing which medical monitoring method?

4 Who is credited with coining the terms "scientist", "astigmatism" and "linguistics"?

5 The pnictogens make up which group of the periodic table?

Answers on page 55

Puzzle
set by Alison Kiddle
#138 Ice cream coincidence

SHUTTERSTOCK/VECTOR TRADITION

Mr Slippy owns two ice cream vans. His staff check the temperature of the freezers every hour to make sure nothing melts. One day, the freezer in Van A is at -13°C at 1pm and -18°C at 2pm. Meanwhile, Van B's driver logs the temperatures as -12°C at 1pm and -20°C at 2pm.

Mr Slippy is certain that there must have been a time when both freezers were at exactly the same temperature but his drivers say it isn't possible to know for sure. Who is right?

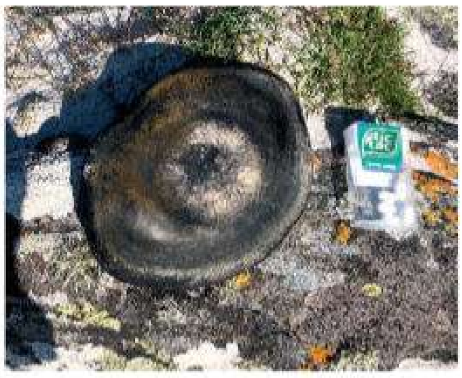
Solution next week

Beach blob

What is this object (pictured below), found in the surf off the Isle of Mull in Scotland? It was originally dark and got lighter as it dried out. It has an odd smell.

Conor Ryan
Tobermory, Isle of Mull, UK
It looks like a layer of cartilage called an epiphyseal plate from a cetacean vertebra. When decaying in the sea, cetacean bones often acquire black bacterial mats, which fade when the bacteria die in air. The plate's proportions are consistent with a medium-sized whale species, such as a minke or long-finned pilot whale. The smell can be reduced by extracting the large amount of oil typically found in cetacean bones with a degreaser.

Chris Daniel
Glan Conwy, Conwy, UK
This appears to be a so-called "sea bean" from a plant of the genus *Mucuna*, a member of the legume family. It is a bat-pollinated vine that hangs from the rainforest canopy and grows in tropical regions, including the Caribbean and Central America. The seeds get washed into the rivers and then the sea, and can travel thousands of kilometres for many years before being washed onto land.



It is difficult to tell exactly which variety the pictured "beach blob" is. It could be *Mucuna holtonii* from Belize, which would put it on the right side of Central America to be able to travel to the UK. I found a report in the *Bridport & Lyme Regis News* of a similar find in Dorset, UK. The article claims that the seeds can be in the sea for 15 years before being washed onto land and can still be viable

Paul Wood
Hamilton, New Zealand
This could be an example of *Equus* coprolites – fossilised horse poo that has been exposed to seawater for a time. I once found some of this on the seashore at Swansea, UK, many years ago.

KIYOSHI TAKAHASE SEGUNDO/ALAMY

If your brain's atoms were swapped with ones of the same elements, would you still be you?

This week's new questions

Me and my brain **If I could somehow replace every atom in my brain one at a time with the same elements, am I mentally still me?** ***Will Smith**, Basildon, Essex, UK*

Into the void **The universe is expanding, but what exactly is it expanding into?** ***Ian Ferguson**, via email*

On the edge

How do astronomers decide where a galaxy begins and ends?

Mike Follows
Sutton Coldfield, West Midlands, UK
A galaxy is composed of stars held together by the force of gravity. However, relying on starlight to define the extent of a galaxy is like looking at the tip of an iceberg rather than the whole thing.

The edge of a galaxy is poorly defined, arbitrary and probably of little interest to most astronomers. Estimating the radius of a galaxy is a bit like deciding on the thickness of the atmosphere, which is often taken to be about 10 kilometres. However, instead of an abrupt boundary between breathable air and the vacuum of space, this transition is much more gradual.

If the distribution of matter corresponds to what can be seen, then, according to Newton's laws of motion, stars further from the centre of a spiral galaxy should be orbiting more slowly. However, this wasn't observed by astronomer Vera Rubin and her team in the 1970s. Instead, they saw that the orbital speed of stars in spiral arms is constant, no matter how distant they are from the galactic centre. This, plus the fact that galaxies spin faster than expected, implies that an invisible halo of dark matter provides the extra force of gravity required to stop them flying apart.

The visible diameter of the Milky Way is estimated to be around 129,000 light years. However, when the dark matter halo is taken into account, this diameter extends to nearly 2 million light years, with an uncertainty of about 20 per cent.

John Davies
Lancaster, UK
When I think about the space between the galaxies, I remember Douglas Adams, who said: "Space is big. You just won't believe how vastly, hugely, mind-bogglingly big it is. I mean, you may think it's a long way down the road to the chemist's, but that's just peanuts to space."

The nearest neighbour to our Milky Way is the Canis Major dwarf galaxy, which is 25,000 light years away, while the nearest large galaxy is the Andromeda galaxy, 2.5 million light years away. In between them is space, vast and empty, save for some gas and dust.

Gravity has drawn the material that formed the stars into the galaxies, leaving little behind. But galaxy formation – and collision in particular – is a violent process and stars do get flung out of them, like sparks from a grinding wheel. Intergalactic stars are known to exist, and 10 per cent of the stars in the Virgo cluster of galaxies (65 million light years away) may not be attached to any of them. Such stars move exceedingly fast, like those sparks, and some of the 600 or so found between the Milky Way and Andromeda galaxies may be retreating away at millions of kilometres an hour.

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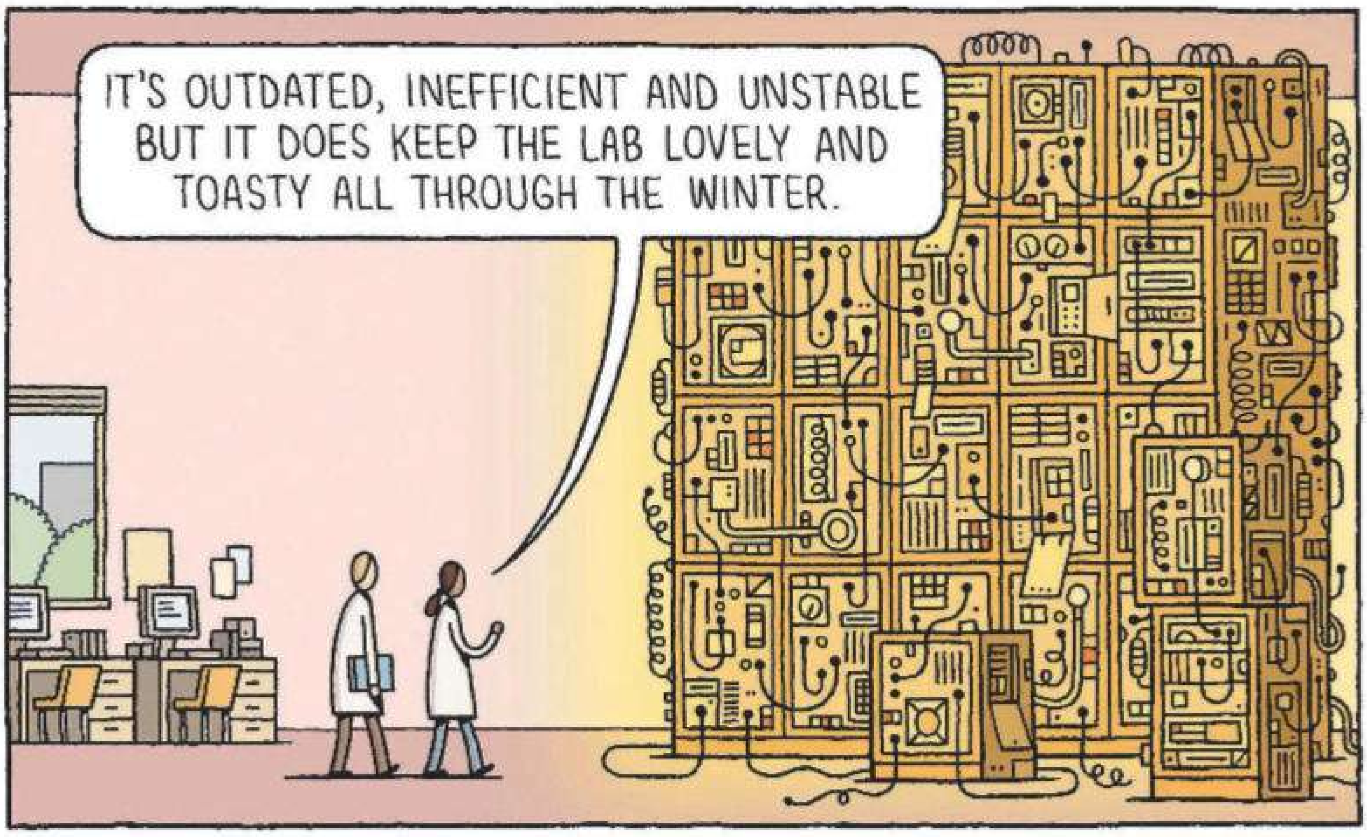
Tom Gauld

for New Scientist


IT'S OUTDATED, INEFFICIENT AND UNSTABLE BUT IT DOES KEEP THE LAB LOVELY AND TOASTY ALL THROUGH THE WINTER.

Tied up

What is the best way to tie shoelaces? Mine never stay tied for very long. (continued)

Peter Martin
Belvèze, France

A simple method to keep shoelaces from untying is to wax them. Beeswax works best. Just make a wad of it and rub it into the laces, either round or flat. It also keeps the laces waterproof and helps them last longer.

Jon Hinwood
Melbourne, Australia

The trick of tying shoelaces securely by wrapping an extra turn around the other lace before completing the loop is well known to fishers. With a slippery nylon line, four or five turns are used to attach the hook. The technique goes back to antiquity, with one of the oldest extant examples probably being the rope wrapped around the horizontal spindle of the winches used to raise a bucket of water in a well.

> **"A thief knot was used for tying parcels when it was suspected they might be broken into. It showed if the parcel had been opened"**

This knot works by increasing the contact surface between one lace and the other, on which friction acts. The friction force also depends on the force perpendicular to the contact surface, which in turn depends on the tension in the laces.

In the reef knot, the laces are parallel, whereas in the granny knot, the second loop is perpendicular to the first, so the laces cross instead of lying alongside each other. This reduces the contact area and the friction forces. To pull a tight reef knot undone, you can try pulling the ends cross-wise as if it were a granny knot, reducing the force and allowing it to slip. This weakness of the reef knot led to the Scouts being taught not to use a reef knot for critical applications.

Andy Bebington
Croydon, UK

Previous correspondence on the topic of the best way to tie shoelaces (2 October) discussed two sorts of double knot, but overlooked the thief knot. This is like a reef knot, but the layout differs in that the two "loose ends" are on opposite sides; on a pure reef, they are on the same side.

A thief knot was used for tying up parcels when it was suspected that the parcel might be broken into. It was assumed that the thief, when tying the parcel up again, would automatically use a reef knot, showing that the parcel had been opened.

John Davenport
London, UK

The previous answers considered only knots and the downstream loose ends. But what is most important is the tightness of the upstream lace grid between the holes. If the laces are tight here, whatever form the grid takes, then you only need a half knot and a simple, easily undone bow.

Answers

Quick quiz #126
Answers

1 Nix, which is a moon of Pluto
2 It has evolved from a non-crab-like form to a crab-like form
3 Electroencephalography (EEG)
4 William Whewell
5 Group 15

Cryptic crossword #69 *Answers*

ACROSS 7 Bolete, **8** Icarus, **10/15** Hen of the woods, **11** Girolle, **13** Nylon, **17** Embalms, **20** Penny bun, **21** Apps, **23** Cilium, **24** Twitch

DOWN 1 Coca, **2** Teredo, **3** Keyhole, **4/9** Lions mane, **5** Mayfly, **6** Mushroom, **12** Isomeric, **14** Amanita, **16** Dunlin, **18** Agaric, **19** H-bomb, **22** Pact

#137 Tricky treaty
Solution

James gained one piece of candy in the deal. There are two ways in which the four children's piles of sweets could have differences in size of one through to six: (X, X, _, _, X, _, X), or the mirror image (X, _, X, _, _, X, X). For example, if the child with fewest got three pieces, the two ways would be (3, 4, 7 and 9 pieces) or (3, 5, 8 and 9 pieces).

When taking them into one pile and dividing that into four, the first way will result in a remainder of three sweets, the second in a remainder of one. Since I took three pieces and divided evenly, we can deduce that it was the first way. We know that James had one more than another child, so he had the second smallest amount, and when the pieces are averaged out, he gains one piece.

Gone with the wind

How do natural disasters affect intimate relationships? Feedback maintains a long list of questions we had never thought of asking, a fact that will surprise no one who knows of our predilection for impossible logic. So we are pleased to see this query now comprehensively answered in the paper "Experiencing a natural disaster temporarily boosts relationship satisfaction in newlywed couples" by Hannah Williamson at the University of Texas at Austin and her colleagues.

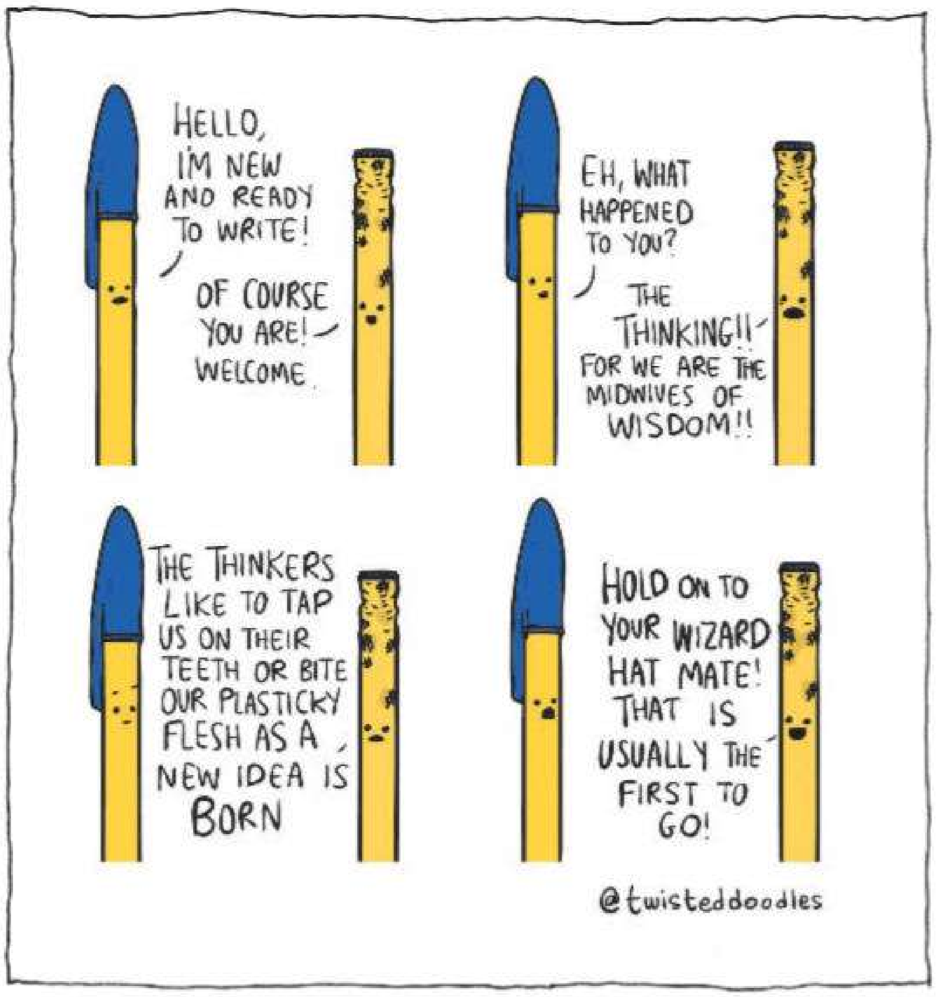
The study involved 231 couples in Harris county, Texas, around the time of Hurricane Harvey in 2017, and is the "first to use longitudinal data collected before and after a natural disaster to examine its effect on relationship outcomes". This rather raises the question in our mind of how long the researchers were waiting, patiently observing, for disaster to strike – or perhaps it is merely a case of when, rather than if, in that part of Texas. Or maybe they have a button they can press, in which case we think we and the ethics board should be told.

No matter: for anyone wondering whether a fortuitously timed tornado might put the whirlwind back into their romance, whether a wildfire can relight their fire or whether Earth moving makes the earth move, the answer is yes – but make hay while the sun's not shining. Couples soon "revert to their prehurricane levels of functioning as the recovery period continues". For a longer-term boost, you will just have to move to somewhere more dangerous.

Block head

Feedback is excited to learn that an article in *New Scientist* has been cited in the defence of Mike Graham, the presenter at talkRADIO – a UK radio station where the opinions can be as suddenly shouty as the name – who claimed while interviewing environmental activist Cameron Ford that you can grow concrete.

Twisteddoodles *for New Scientist*


HELLO, I'M NEW AND READY TO WRITE!
OF COURSE YOU ARE! WELCOME.
EH, WHAT HAPPENED TO YOU?
THE THINKING!! FOR WE ARE THE MIDWIVES OF WISDOM!!
THE THINKERS LIKE TO TAP US ON THEIR TEETH OR BITE OUR PLASTICKY FLESH AS A NEW IDEA IS BORN
HOLD ON TO YOUR WIZARD HAT MATE! THAT IS USUALLY THE FIRST TO GO!
@twisteddoodles

Got a story for Feedback?

Send it to feedback@newscientist.com or New Scientist, Northcliffe House, 2 Derry Street, London W8 5TT

Consideration of items sent in the post will be delayed

We fear the clues may be in the quotes in the headline, "Living 'concrete' made from bacteria used to create replicating bricks", and in the first line of the article, "A type of living concrete made from bacteria could one day help to reduce the environmental impact of the construction industry".

No, Mike and all: to the best of our knowledge, we cannot grow concrete. Mind you, with all the wonderful things we are learning you can do with cellulose, grasping at straws may prove to be a viable alternative.

Taking the low road

"They got you covered, either way", is Quentin Macilray's comment as he writes from Santo Domingo in the Dominican Republic with a picture of a van advertising Camino Eterno, a combined ambulance and undertaking service. We can't better Quentin's description of it as a quantum business governed by the collapse – or not – of the customer's wave function. We are left wondering about the quality of the driving.

Menage au fromage

This week's prize for research that made us involuntarily choke on our cocoa is "Sex in cheese: evidence for sexuality in the fungus *Penicillium roqueforti*".

Our late-night stilton eating may never be as innocent again with the revelation that, far from living a life of monastic asceticism and reproducing purely asexually, the little blue-cheese-making blighters are – we know of no way to put this delicately – at it all the time. "The screening of a large sample of strains isolated from diverse substrates throughout the world revealed the existence of individuals of both mating types, even in the very same cheese," the researchers write, with what sounds like glee.

Investigating the sexual capabilities of cheese mould isn't something we had considered as a calling before. The affiliation of the team involved – the National Museum of Natural History in Paris, France – causes us to narrow our eyes ever so slightly, while giving the faintest of wise nods.

Where's my elephant?

Nick Parlow writes taking exception to a suggestion made in our thread on finding an elephant in the room (4 September and 2 October). "I'm sure that others have pointed out how ludicrous it is to paint an elephant's toenails red and hide it in a cherry tree," he writes. "That amount of red nail varnish would be prohibitively expensive. Happily there is a far more practical method: paint the soles of its feet yellow, and hide it upside down in the custard."

We are pleased to make this plain, Nick, given also that you reference the source "Cunningham and Blake (1974), *The Puffin Joke Book*", leaving us in no doubt that this is settled science and that the old ones are the best.

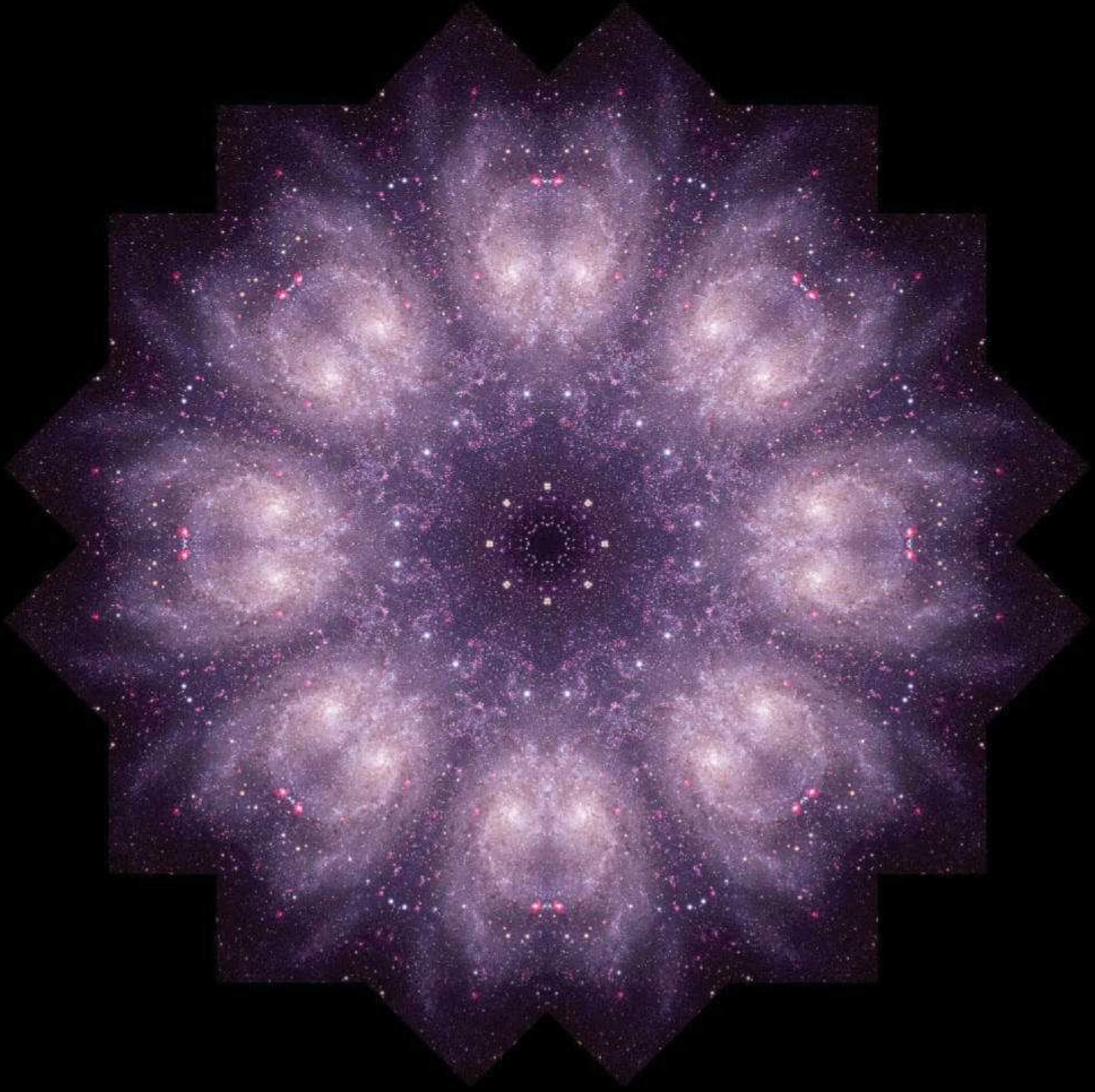
Elementary errors

While in the vein of *nostra culpa*, opprobrium – an alkaline earth metal, we believe – has rained down on the Feedback inbox following an ad for *New Scientist* subscriptions in our 23 October issue. With the tagline "That's elementary", it promised the gift of some rather surprising chemistry this Christmas. The non-metal selenium became a lanthanide, while both the transition metal rhenium and the excitingly short-lived halogen tennessine were Nobel gases.

No prizes there. Apologies to all who felt pH-imbalanced, and for all those asking what we intend to do with those responsible: barium. ■

GALAXY
ON GLASS

SPECTACULAR WALL ART FROM
ASTROPHOTOGRAPHER CHRIS BAKER



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